The Health Status of Dentists Exposed to Mercury from Silver Amalgam Tooth Restorations

Thomas G. Duplinsky[1,*] and Domenic V. Cicchetti[2]

[1]*Department of Surgery, Yale University School of Medicine, USA*

[2]*Child Study Center and Departments of Biometry and Psychiatry, Yale University School of Medicine, USA*

Abstract: The authors employed pharmacy utilization data to evaluate the health status of a representative sample of 600 dentists, matched to control subjects, for gender, age, geographical area, and insurance plan structure. Dentists demonstrated significantly more prescription utilization of specific illness medications than did Controls, for the following disease categories: Neuropsychological, Neurological, Respiratory, and Cardiovascular. The greater majority of pediatric and general practice dentists still use mercury amalgam restorations. This places them at greater risk than the general population for those disorders, as well as threatening the future health of America's children and adults who continue to receive silver amalgam restorations.

Keywords: Pharmacy Utilization, Mortality Studies, Dentists' Health Status, Mercury Exposure.

The purpose of this investigation is to compare the health status of age and gender-matched General Practice Dentists and Controls, in five disease categories: Neuropsychiatric, Neurologic, Combined Neuropsychiatric and Neurologic, Respiratory and Cardiovascular disorders.

The public has been concerned for a number of years about their silver amalgam tooth fillings from the standpoint that these fillings contain 50% mercury (Enwonwu, 1987; Pleva, 1994) [1-2]. It is well established that low levels of mercury are continuously released from silver amalgam fillings (Aronsson, *et al*., 1989; Clarkson, *et al*., 1988; Patterson, *et al*., 1985; Svare, *et al*., 1981; Vimy & Lorscheider, 1985; Vimy & Lorscheider, 1990; and the World Health Organization, 1991) [3-9].

Despite the controversy over mercury exposure, amalgam is still in wide use based on the fact that, as yet, no disease process has been directly linked to this type of filling. The dentist who places and removes this type of filling is exposed to higher levels of mercury vapor than is the general population. Dentists have been shown to have a higher urine mercury level, and a higher mercury body burden than the general population (Chang, *et al*., 1992; Martin, *et al*., 1995; and Naleway, *et al*., 1985) [10-12].

The defenders of the continued use of mercury amalgam fillings state that there is no evidence to suggest that dentists suffer any ill effects as a result of this higher exposure to mercury. In fact, based on mortality studies and surveys, a number of authors have argued that dentists tend to be healthier than the general population (Bureau of Economic Research and Statistics, 1975; Office of Population Censuses and Surveys, 1978, 1986; Leigh, 1987; and Orner, 1976) [13-17]. Another popular belief is that dentists, having a higher body burden of mercury than the general population (Martin, *et al*., 1995) [11] have a greater life expectancy than the general population despite their prolonged increased exposure to mercury (Berry, 1998) [18]. Authors go even further to say that the finding that dentists as a group have higher mercury levels than those associated with people with amalgam restorations, but experience no increase in disease or death rates, is an important reassurance to both patients and dentists with respect to the safety of amalgam (McComb, 1997) [19].

In an attempt to resolve what he described as the "amalgam controversy, Dodes (2001) [20] sought to perform an "evidence-based analysis" of both the peer reviewed and non-peer reviewed dental amalgam literature. In order to accomplish this goal, Dodes put forth a number of criteria to evaluate each study. These included the following: proper random assignment; follow-up procedures, including drop-out rates; whether study groups were analyzed in the group to which they were assigned; whether the study was blinded; whether the groups, except for the experimental intervention, were treated equally; whether the statistical analyses were undertaken appropriately; whether chance findings were misinterpreted for statistically valid ones; whether participants' compliance was measured appropriately; whether all clinically significant outcomes were discussed; whether side effects/negative effects were reported and discussed; whether the treatment

*Address correspondence to this author at the Yale Department of Surgery, 1220 Whitney Avenue, Unit C-10, Hamden, CT 06517, USA;
Tel: 203-287-8570; E-mail: Thomas.Duplinsky@ynhh.org

E-ISSN: 1929-6029/12

benefits outweighed negative effects and study costs; and applicability of the results to a particular patient. Dodes concluded that amalgam restorations remain safe and effective; and that dentists should educate patients and other health care professionals who may be mistakenly concerned about amalgam safety (p.48).

Unfortunately, the Dodes (2001) review [20] is fraught with flawed scientific reasoning. Major among its deficiencies are the following: (1) The guidelines that were developed and just delineated were never applied to any of the reported studies; (2) Two Studies by Uzzell & Oler (1986) [21]; and by Shapiro, *et al*., (1982) [22], that had long ago established the neuropsychological, neurological and psychiatric effects of low level dental amalgam mercury exposure in both dentists and other dental workers were never cited at all; and, finally (3) Dodes [20] averred without offering a single concrete example:

> " …that analysis of the data concerning daily mercury release and absorption leads me to conclude that mathematical errors led to serious miscalculations in arriving at the total amount of mercury vapor exposure. These computational errors led many investigators to overestimate the amount of mercury that is released and absorbed during daily life (p.351).

Our central research goal is to test whether dentists show ill health effects from being occupationally exposed to mercury vapor. The results of this research endeavor would help to illuminate a critical issue that has yet to be resolved satisfactorily. Specifically, if dentists are as healthy as, or healthier than the general population, as one body of research literature maintains (Balarajan, 1989; Dodes, 2001; Langworth, *et al*., 1997; Mandel, 1993; McComb, 1997; Orner, 1978; and Zwemer, 1987) [19, 20, 23-27] then perhaps the mercury released from amalgam fillings is not an issue.

However, if dentists are experiencing negative health effects, as suggested by another and contrasting body of evidence (Echeveirria, *et al*., 1998); and Uzzell & Oler, 1986) [21, 28], then the concern over the mercury released from silver amalgam fillings is, in fact, justified.

It is our contention that the primary reason why this fundamental controversy continues to exist is because of what we consider the essentially flawed methodological research designs that have characterized much of the research that has supported the hypothesis that dentists fare as well, or better in their basic health status than do their general population counterparts. Put succinctly, the controversy centers around answering appropriately, with both state-of-the-art methodology and statistical approaches the question:

How can the health status of a population of dentists be efficiently and effectively measured?

There are several methods that have been used to study the health of populations which include the use of subject surveys, interview surveys, hospital chart reviews, and mortality studies, each with its own inherent weaknesses (Gordis, 1996) [29]. The subject filled out survey tells what the subject thinks is happening, which may not be accurate. The interview survey is labor intensive and subject to specific error. The hospital chart review may be missing critical information. Mortality data are fraught with the problems of a vague cause of death determined by many medical examiners and limited autopsy results (Gordis, 1996, p.35) [29].

All this said there are some well-designed studies in the research literature in which the authors were able to successfully measure the effects of mercury exposure upon the neurological and neuropsychological health of: (a) dentists (Shapiro, *et al*., 1982) [22]; and (b) female dental workers (Uzzell& Oler, 1986) [21].

Shapiro and colleagues (1982) [22] compared 23 dentists with >20 µg/g tissue mercury levels to an age-matched control group of 22 dentists with no detectable levels of mercury. Results indicated that: (1) the mercury exposed dentists had significantly slower sensory and motor conduction velocities than did controls ($p<.05$). (2) Five of the mercury exposed dentists, but none of the controls, had what Shapiro, *et al*. (1982), p.1148) [22] classified as "electrophysiological abnormalities consistent with the carpal tunnel syndrome (CTS) -i.e., a median motor distal latency greater than 4.6 ms and/or slowed median sensory conduction scores across the wrist, but normal median motor conduction in the forearm" ($p= .03$); (3) Fourteen of the mercury exposed dentists, compared to 3 control dentists, manifested significantly higher distress levels, with levels higher than those within the normal range ($p <.05$). (4) Finally, it is noteworthy that full-scale IQ scores derived from the

Wechsler Adult Intelligence Scale (WAIS) were virtually identical.

In a second investigation, Uzzell & Oler (1996) [21] compared the effects of low level mercury exposure ($\leq$ 20 µg/g) in 13 female dental workers to 13 controls with no measureable mercury levels, upon neuropsychological functioning. The two groups were carefully matched on average age (41 years), educational level, and number of years performing dental work (15 years). After controlling for the chance effect of multiple comparisons by standard Bonferroni adjustments (e.g. Toothaker, 1991) [30], the following results were reported: the workers with detectable mercury levels scored significantly lower on picture recognition (Kimura, 1963) [31]; as well as on word recognition; and had higher levels of psychiatric symptomatology (Derogatis, *et al*., 1977) [32]. Consistent with the Shapiro, *et al*., 1982 investigation [22], WAIS total IQ scores of the two groups were virtually identical.

The results of both these investigations are consistent with the results of two more recent investigations. In a meta-analytic investigation of 12 studies, Meyer-Baron, *et al*., (2002) [33] examined the dosage effects of occupational creatinine Mercury levels upon neuropsychological test performance. Significant deficits in psychomotor performance were demonstrated across all studies. In one of the included studies, Liang, *et al*., (1993) [34] reported that at mean levels of 25 µg/g study subjects demonstrated deficits across a wide range of neuropsychological tests. These included tests measuring attention, motor speed, motor precision, perception, and reasoning. In a follow-up investigation, Meyer-Baron, *et al*., (2004) [35] examined dose-response levels to neuropsychological test performance of subjects exposed to inorganic Mercury. The greatest impairment, as measured by Mercury creatinine, occurred in psychomotor performance. Mercury exposure levels ranged between 3 µg/g and 192 µg/g with a mean of 39 µg/g.

While it is known that chronic exposure to very high levels of Mercury will invariably produce neuropsychological deficits and other health problems (most recently, Jones, *et al*., 2007) [36], the studies just reviewed indicate that deficits can and will occur at relatively low dosages below 20 µg/g, as in Uzzell & Oler (1986) [21].

In each of three recent clinical trials, more than 500 children were randomized either to a mercury amalgam restoration condition or a resin composite restoration control group (Bellinger, *et al*., 2006; De Rouen, *et al*., 2006; and Lauterbach, *et al*., 2008) [37-39].

In the Bellinger, *et al*. (2006) investigation [37], the children ranged in age between 6 and 10 years; and were followed for 5 years. The primary outcome measure was a change in total IQ between baseline and a 5 year follow-up. Secondary outcome variables included 4 year changes in tests of visuomotor ability and memory, as well as, changes in urinary albumin. No statistically significant differences were found at follow-up periods, relative to baseline, for any of the dependent measures.

There are two very serious problems that serve as threats to the validity of the reported negative findings. The first, and most serious, is the unfortunate choice of change in IQ as the major outcome variable. As previously noted, two well-designed earlier studies indicated that: while both female dental workers (Uzzell & Oler, 1986) [21] and dentists (Shapiro, *et al*., 1982) [22] who were exposed to low levels of mercury had significantly higher levels of neuropsychological, neurological, and neuropsychiatric symptomology, than did matched controls, mercury exposure had no effects whatsoever upon total WAIS IQ levels. Similarly, O'Carroll, *et al*., 1995 [40] described a case of severe occupational poisoning due to very high levels of inorganic mercury exposure that produced major neurological and psychiatric sequelae but, again, no effects on level of IQ. Given these strong results, the choice of IQ as a major outcome variable was not a reasonable one. It is noteworthy that Bellinger, *et al*. (2006) [37] did not cite either of these earlier and seminal studies. It appears safe to assume that the authors were not aware of this prior research or they would never have chosen to use total IQ as the major outcome measure. The second threat to the validity of the reported results is that the approximately 25% of children lost to follow-up analysis differed from the retained sample, as follows: They had lower baseline IQ's; they were predominantly from the Boston area; they were of minority ethnic status (mostly Hispanic); and they were lower in socio-economic status, as reflected in lower parental income and level of educational achievement. Variables such as these indicate children who may have been among the most vulnerable to the effects of mercury exposure. The authors' defense of this non-random status of children lost to follow-up, namely, that the demographic characteristics of the retained samples were comparable, is not in any way convincing, since it

merely indicated that the children lost to follow-up were just as biased in the dental amalgam group as in the dental composite group. The second study, by DeRouen, *et al*. (2006) [38] shares a number of methodological/design features with the Bellinger, *et al*. investigation [37]: it too is a clinical trial comparing children who were: (a) randomized to either a dental mercury amalgam condition or to a resin composite restoration control condition: and (b) studied yearly from baseline, for a period of 7 years. The outcome measures are similar, as well, and included: (a) the primary variables, tests of memory, attention/concentration, visuomotor and nerve conduction velocity; and (b) the secondary variables, tests of intelligence or cognition. Again, there were no statistically significant differences between the amalgam and resin composite restoration groups on any of the primary or secondary variables, either at baseline, or at 2, 3, 4, 5, 6, and 7 years follow-up annual assessments.

Finally, substantial numbers of patients were lost to follow-up assessment. By year seven, 44% in the Amalgam condition had missing urinary albumin levels compared to 43% who had missing values in the Resin Composite condition. No attempt was made to compare the demographic profile of those lost to follow-up to those children who had complete data.

The most recent clinical trial comparing neurological outcomes in children with and without amalgam dental restorations was conducted in Portugal by Lauterbach, *et al*.,(2008) [39]. 507 children, between 8 and 12 years of age were randomized to either an amalgam or resin-based dental restoration condition, and followed for 7 years. The outcome variables were neurological soft and hard signs and the presence of tremor.

The authors report no statistically significant neurologic differences between the amalgam and control group on any of the neurologic measures. This investigation was also plagued by serious design flaws. These included: too short a follow-up assessment period and substantial loss of subjects to follow-up assessments. Specifically:

For the neurologic soft sign measurements, there was a 41% loss between the first and last assessment, for the Amalgam restoration group. Similarly, there was a corresponding 36% loss between these two assessment periods for the Composite restoration group. No attempt was made to identify the potential biasing effects of these high attrition rates upon the accurate reporting of the meaning of the obtained results.

The follow-up data for hard neurological signs, as well as that for presence of tremor, followed similar patterns of very high attrition rates, again, with no attempt to explain potential biasing effects. These figures, again comparing the second and seventh follow-up assessment, showed a 46% attrition rate for the Amalgam condition and 43% for the Resin composite group.

The data on tremors were even more problematic: Only 60% of subjects in the Amalgam condition were initially assessed. Similarly, 58% of the children in the resin composite group were not assessed for tremors at the initial assessment period. Again, no attempt was made to assess the effects of such high attrition rates upon the accuracy of the reported results.

In summary, the serious design flaws in each of these three trials cast doubt on the authors' conclusions in both clinical trials that the results confirm that dental amalgams are a safe option for children's dental restorations. The data, as we have demonstrated simply do not support what we view as an incorrect conclusion.

METHODS

Insurance Utilization

In this study, the senior author developed a method using insurance utilization data as a tool to determine the health status of a population of general dentists. This paper will report the results of an investigation that examines pharmacy utilization data as an indicator of the health of a population. This state-of-the-art method obviates the flaws of previously cited earlier studies that utilized alternative methodologies.

Pharmacy claims data are much easier to use than medical claims data, because the advent of "Managed Care" has weakened the medical claims data source. Restricted medical care utilization imposed by managed care, and the wide range of deductibles make it possible to miss health conditions. For example, the diabetic with a $500 deductible may not reach the deductible for the year, and would therefore be invisible to analysis.

Pharmacy utilization is still basically first dollar or small co-pay. People, for the most part, will not go without their prescribed medication, but may limit visits

to the physician. The basic premise for this approach is that patients are prescribed medication to treat a specific disorder, and it is irrelevant for this analysis whether they are compliant with taking the medication. This study looks at actually filled prescription data. The authors were granted permission by study participants to obtain access to pharmacy claims data, medical claims data, and biographical data on a random and, as will be shown, representative population of general practice male dentists.

Constructing the Study Samples

A pharmaceutical benefits manager (PBM) and a third party administrator (TPA) were contacted in order to obtain data.

The PBM insures over 200,000 people in the North Eastern section of the United States. From this geographical population, a group of 600 dentists was used, along with a matched control group of 1109 adults. Drug utilization data was collected over a 16 month period, from November 1997 to February 1999.

Subject Identity Protection

It was very important to all concerned that the identity of the insured groups, the individual subject, the PBM, the TPA, and the geographical area be protected. The population data base was developed by the PBM using a social security number identifier. Data were transmitted to the authors for analysis with the social security number identifier modified by an altering algorithm, thus protecting subject anonymity.

Matching Dentist Group with Control Group

The following characteristics are common to both the dentist group and the control group: they are from the same geographic area; they have the same PBM; many of the test subjects and control subjects have the same physician; they have the same prescription drug card and card restrictions; and only the claims for drugs prescribed by a physician were used. The Drug Enforcement Administration (DEA) number of the prescriber was used by the PBM to identify any dentist self-prescribed medication. In order to avoid potential biases, those dentists who self-prescribed were not included in the study. According to the PBM, the dentist group represented the highest prescription drug utilizers among the 200,000 insureds, and therefore had the highest paid loss ratio.

The control group was also selected on the basis of a comparable age and sex distribution. The PBM selected a control group that had a typical utilization history (paid loss ratio) of the 200,000 insureds. Of most importance, the control subjects were characterized as to white-collar, blue-collar job status. The white collar group, at 15%, is composed of managers, administrators, lawyers, and engineers; and the blue collar, at 85%, is composed of factory workers, secretaries, tradesmen, and skilled industrial support personnel.

Developing a Representative Group of Dentists

The first question that must be answered here is how representative is the study group of dentists to the total population of dentists? Table **1** compares the study group dental specialty distribution to the total geographical area dentist population and the total national dentist population. The geographical area of the study contains a total of 2175 dentists. The 600 dentists in the study are derived from this total group of dentists. This sample of 600 is 28% of the total dentists in this geographic area.

Refining the Dentist Population

It was decided to use only general practice dentists for analysis because the number of subjects in each dental specialty was too small to be statistically reliable. There were 440 general practice dentists, of which only 29 were female. Consequently, the final study population is composed solely of male general dentists. The dentist study group of 396 was derived after subtracting the 29 females and the 15 self-prescribing dentists. The 708 controls are males left after all females have been subtracted from this group.

The geographical area of the study contains a total of 1549 general practice dentists. The average age of the general practice dentists in the study population is 49 years old, compared to 48 years old for the total general practice dentists in this geographical area.

Data Base

The data used in this study reflect a combination of census information, raw prescription claims, National Drug Code (NBC) information, our own drug categories, dentist specialty information and miscellaneous code and description tables such as gender description and age groups tables.

Microsoft Access 97 was used as the data-base engine. Esperant, an ad-hoc query and reporting tool

Table 1:

Study Population Specialty	Study Population Count	Study Population Distribution
Endotontics	24	4.0%
General Practice	440	73.3%
Oral and Maxillofacial	31	5.2%
Orthodontics	41	6.8%
Pediatric Dentistry	16	2.7%
Periodontics	35	5.8%
Prosthodontics	13	2.2%
Total	600	
Regional Specialty	**Regional Count**	**Regional Distribution**
Endodontics	60	2.8%
General Practice	1549	71.2%
Oral and Maxillofacial	133	6.1%
Orthodontics	174	8.0%
Pediatric Dentistry	73	3.4%
Periodontics	97	4.5%
Prosthodontics	38	1.7%
Unknown	51	2.3%
Total	2175	
National Specialty		**National Distribution**
Endodontics		2.2%
General Practice		79.5%
Oral and Maxillofacial		4.1%
Orthodontics		5.8%
Pediatric Dentistry		2.4%
Periodontics		3.1%
Prosthodontics		2.0%

was used to do the actual analysis and produce the reports. A combination of C++ and Java was used for the custom programming required to process and reformat the data.

National Drug Codes

The claims data used in this study contained a drug code using the Health Care Financing Administration's (HCFA) NDC coding scheme to identify the drug. We downloaded the standard HCFA NDC table available to the public on the HCFA World Wide Web site (http://www.fda.gov/cder/ndc/index.ht). From this table, we extracted the NDC code and description (label name) fields.

NDC Categories

We wanted to categorize the drug information by type and use of drug, not by the individual drug label name and dosage. HCFA provides just such a categorization table. However, we quickly determined that the drug categories provided by HCFA were not usable for this study. The HCFA drug categories allow the same drug to appear in different drug categories (i.e. some drugs have multiple uses). We needed any given drug to appear in one and only one category. Thus, we developed our own NDC category table for this study. The NDC code was used as the primary key for this table.

Study Drug Categories

The four major drug categories selected for use in this study are: neuropsychological, neurological, cardiovascular, and respiratory. These categories are broad enough by design that there is no overlap in drug use. The four categories closely follow the major disease categories developed by the World Health

Organization for the International Classification of Diseases (ICD-9), which is published in the United States by the Health Care Financing Administration (HCFA). For example, the non-neuropsychological, neurological category contains medications such as anticonvulsants, anti-migraine, anti-vertigo, and anti-Parkinson's medications.

The Third party Administrator provided medical claims data in ICD-9 form for 400 of the dentist study subjects. This allowed the drug categories to be compared to the medical diagnosis for which the subject was being treated. The four major drug categories used in this study match the medical diagnostic code completely for the 400 subjects. This is not surprising considering that the ICD-9 and NDC coding systems are designed to be in agreement. Table **2** gives a sample comparison of the ICD-9 derived medical diagnosis and the NDC derived drug. This finding indicates how useful pharmacy utilization data alone can be in evaluating health status.

Study Hypotheses

Three study hypotheses were formulated, as follows:

1. Combined over all age ranges (25-34; 35-44; 45-54; 55-64), and separately for each disease category, Dentists will be on significantly more prescription medications than will Controls.

2. For each disease category there will be a trend such that with increasing age levels, there will be an increasing frequency of utilization of prescription medications, and, further, that within specific age ranges, Dentists will be higher on pharmacy utilization, meaning that they will purchase more specific illness medication than will Controls. This means that the resulting 8 groups will rank themselves, from lowest to highest drug prescription utilization patterns, as follows:

Controls (25-34)

Dentists (25-24)

Controls (35-44)

Dentists (35-44)

Controls (45-54)

Dentists (45-54)

Controls (55-64)

Dentists (55-64), and, finally, the third hypothesis is that:

3. For each disease category, at each of the age ranges, Dentists will purchase more illness-specific prescribed medications than will Controls, and, further that this will have its greatest effect at the older age ranges.

Statistical Analyses

To evaluate the health status of General Practice Male Dentists (hereafter referred to as Dentists) and age and gender matched Controls, we will utilize three data analytic approaches to compare the two groups on the frequency with which they utilize prescription medications for the five categories of mental and physical illnesses: Neuropsychological, Neurological, the Combination of Neuropsychological and Neurological, Respiratory, and Cardiovascular. The data need to be evaluated from three perspectives, to effectively test the study hypotheses.

The first is to test the overall hypothesis that Dentists, as a total group, will have a significantly

Table 2: Sample ICD-9 Code Diagnosis Compared to NDC

ICD-9 Category	ICD-9 Diagnosis	NDC Drug
Mental Disorders	Neurotic Depression Bipolar Affective Disorder	Fluoxetine Lithium
Nervous System	Migraine Headache Epilepsy Parkinson's Disease	Sumatriptan succinate Gabapentin Levodopa / Carbidopa
Respiratory System	Asthma	Salmeterol
Circulatory System	Ischemic Heart Disease Atrial Fibrillation Malignant Hypertension	Diltiazem Quinidine Lisinopril

greater frequency of taking illness-specific medications than will the total group of Controls; and that this finding will hold for each of the five aforementioned disease categories. This will be accomplished by applying the standard chi-squared test using the required Yates (1934) correction for continuity [41], as convincingly argued by Fleiss, *et al*., (2003, pp.57-58) [42]. It should be noted here that the chi-squared test, in this form, is mathematically equivalent to the less familiar Fisher's Exact Probability Test (providing the total number of cases is 40, a criterion that is easily met in all our data sets). We will also employ the frequently applied relative risk ratio that is simply the ratio of the risk of the occurrence of an event (in our case, prescription medication utilization) specific to the *presence* of a given factor (in our case, being a general practice dentist), relative to the risk of the same phenomenon occurring in the *absence* of the same factor (in our case being an age and gender matched control). The conceptual and mathematical relationships and similarities among the chi-squared test and the relative risk ratio is given in Fleiss, *et al*., (2003) [42].

The second hypothesis is that for each of the five disease categories, there will be an increasing percentage for Dentists, compared to Controls, purchasing illness-specific prescription medications; and that this will hold true within each of the four age groupings.

This translates into the following specific predicted rankings of prescribed medication purchases (Lowest to Highest) of the 8 Groups of study subjects:

(1) Controls (25-34); (2) Dentists (25-34); (3) Controls (35-44); (4) Dentists (35-44); (5) Controls (45-54); (6) Dentists (45-54); (7) Controls (55-64); and (8) Dentists (55-64).

An appropriate computer program for examining data of this type was developed by Cicchetti, Showalter, Rourke, & Fuerst (1992) [43]. In statistical terminology, we are testing for an ordinal trend (the 8 age groupings) with a dichotomous outcome (the proportion of study subjects who did or did not purchase illness-specific prescription medications). The ranked age groups refer to the independent or classification variable; and the proportions of illness-specific utilization of prescription medications define the dependent or outcome variable. An appropriate statistic of choice, Jonckheere's Z, was utilized in the aforementioned Cicchetti, *et al*. (1992) computer program [43]. It is interpreted in the same way as any other Z statistic, namely, that a value of 1.96 (two-tailed, positive or negative direction) means the predicted trend is statistically significant at a probability (p) level of .05: a Z of 2.24 is at the .025 level; one of 2.58 has a ***p*** of .01; 2.81 reaches the .005 level; a Z of 3.29 is statistically significant at the .001 level; and a Z of 4.00 is significant at beyond the .0001 level of probability. When there are only two levels for the classification variable, the data can be cast into a 2x2 contingency table, and the resulting Jonckheere Z test becomes mathematically equivalent to the square root of the aforementioned Chi squared test with the Yates (1934) [42] correction for continuity. It is also mathematically equivalent to the Fisher's (1935) exact probability test [44].

Table 3: A Comparison of Dentists and Controls in Frequency of Utilizing Illness-Specific Prescription Medications

Illness Category:	Group:	Relative 95%					
		Usage	Percent	χ_c^2	p	Risk (RR)	C.I.
1. Psychiatric	Dentists	46/396	11.6	15.66	<.0001	2.37	1.55-3.62
	Controls	35/708	4.9				
2. Neurologic	Dentists	24/396	6.1	24.17	<.0001	7.63	3.08-18.88
	Controls	6/708	0.8				
3. Psychiatric +	Dentists	61/396	15.4	29.00	<.0001	2.80	1.91-4.11
Neurologic	Controls	39/708	5.5				
4. Respiratory	Dentists	84/396	21.2	7.55	.006	1.46	1.13-1.90
	Controls	103/708	14.5				
5. Cardiovascular	Dentists	107/396	27.0	18.23	<.0001	1.68	1.33-2.12
	Controls	114/708	16.1				

The third hypothesis is that there will be statistically significant differences between Dentists and Controls at specific age groupings, with this reaching a maximum at the two older age groups (45-54) and (55-64).

This hypothesis will be examined using the aforementioned Chi-square (d) test with the required Yates (1934) correction for continuity [41].

RESULTS

Overall Group Comparisons

For each of the five disease categories, Dentists showed a much higher frequency of pharmacy utilization of specific illness prescription medications than did Controls. These data are displayed in Table **3**, and fully confirm the first hypothesis, with *p* values ranging between .006 and <.0001.

Trend Analyses

The second hypothesis, that for each of the five disease categories, there would be an increasing percentage, by age grouping, of pharmacy utilization of illness-specific prescriptions; and that within each of the four age groupings, Dentists would have a higher frequency of purchasing illness-specific medications than would Controls, also received confirmation.

These data are presented in Tables **4** through **8**.

For 4 of the 5 medication categories, the results were again statistically significant at far beyond the .0001 level of statistical probability. For the remaining trend, the utilization of prescription medications for the treatment of Respiratory disorders, the results closely approached statistical significance at the .056 level of probability.

Table 4: Ranking of 8 Groupings of Dentists and Controls in Utilizing Medications for Treating Psychiatric Illnesses

Predicted				
Ranking:	**Psychiatric+**	**Percent+**	**RR**	**95% C.I.**
Controls (25-34)	2/206	1.0		
Dentists (25-34)	0/19	0.0	Not Applicable	
Controls (35-44)	13/214	6.1		
Dentists (35-44)	9/113	8.0	1.31	0.58-2.97
Controls (45-54)	12/190	6.3		
Dentists (45-54)	22/144	15.3	2.43	1.24-4.74
Controls (55-64)	8/98	8.2		
Dentists (55-64)	15/120	12.5	1.52	0.68-3.44

Jonckheere's Z= 4.77; p <.0001.

Table 5: Ranking of 8 Groupings of Dentists and Controls in Utilizing Prescription Medications for Treating Neurologic Illnesses

Predicted				
Ranking:	**Neurologic+**	**Percent+**	**RR**	**95% C.I.**
Controls (25-34)	0/206	0.0		
Dentists (25-34)	0/19	0.0	Not Applicable	
Controls (35-44)	0/214	0.0		
Dentists (35-44)	6/113	5.3	5.30	1.13-24.83
Controls (45-54)	2/190	1.1		
Dentists (45-54)	11/144	7.6	6.91	1.60-29.86
Controls (55-64)	4/98	4.1		
Dentists (55-64)	7/120	5.8	1.41	0.43-4.69

Jonckheere's Z= 4.49; p <.0001.

Table 6: Ranking, by Age Group, of Dentists and Controls in Utilizing Prescription Medications for Psychiatric and/or Neurologic Illnesses

Predicted				
Ranking:	**Psychiatric/Neurologic+**	**Percent+**	**RR**	**95% C.I.**
Controls (25-34)	2/206	1.0		
Dentists (25-34)	0/19	0.0	Not Applicable	
Controls (35-44)	13/214	6.1		
Dentists (35-44)	13/113	11.5	1.89	0.91-3.93
Controls (45-54)	12/190	6.3		
Dentists (45-54)	29/144	20.1	3.19	1.69-6.04
Controls (55-64)	12/98	12.2		
Dentists (55-64)	19/120	15.8	1.30	0.66-2.54

Jonckheere's Z=6.03; p <.0001.

Table 7: Ranking, by Age Group, of Dentists and Controls in Utilizing Prescription Medications for Treating Respiratory Illnesses

Predicted				
Ranking:	**Respiratory+**	**Percent+**	**RR**	**95% C.I.**
Controls (25-34)	29/206	14.6		
Dentists (25-34)	4/19	26.3	1.80	0.79-4.10
Controls (35-44)	32/214	17.3		
Dentists (35-44)	23/113	24.8	1.43	0.93-2.21
Controls (45-54)	25/190	16.3		
Dentists (45-54)	29/144	27.8	1.71	1.13-2.59
Controls (55-64)	17/98	20.4		
Dentists (55-64)	28/120	27.5	1.35	0.83-2.19

Jonckheere's Z= 1.91; p=.056.

Table 8: Ranking, by Age Group, of Dentists and Controls in Utilizing Prescription Medications for Treating Cardiovascular Illnesses

Predicted				
Ranking:	**Cardiovascular+**	**Percent+**	**RR**	**95% C.I.**
Controls (25-34)	4/206	1.9		
Dentists (25-34)	1/19	.3	2.79	0.33-23.69
Controls (35-44)	19/214	8.9		
Dentists (35-44)	8/113	7.1	0.80	0.36-1.76
Controls (45-54)	50/190	26.3		
Dentists (45-54)	42/144	29.2	1.11	0.78-1.57
Controls (55-64)	41/98	41.8		
Dentists (55-64)	56/120	46.7	1.12	0.83-1.51

Jonckheere's Z= 12.46; p <.0001.

Within each of the age groupings (25-34; 35-44; 45-54; and 55-64), there were 5 possible comparisons between Dentists and Controls, within each type of prescription medication (Neuropsychological, Neurological, Combined Neuropsychological and Neurological, Respiratory, and Cardiovascular). This

results in a total of 20 comparisons. In 16/20 or 80% of them Dentists evidenced more utilization of illness specific prescription medications than did Controls. Two of these occurred in the youngest Age Grouping (25-34), for Respiratory and Cardiovascular medications; four in the 35-44 age groupings (Neuropsychiatric, Neurological, total Neuropsychiatric and Neurological, and Respiratory medications). In the remaining 10 instances, Dentists in the two highest age groupings, 45-54 and 55-64, purchased more prescription medications that did Controls for each of the five categories of specific illnesses.

In conclusion, there was strong support for general and specific hypotheses that Dentists would manifest a higher frequency of utilizing illness specific prescription medications than would Controls.

Specific Group Comparisons at Each Age Range

There was also support for the third hypothesis, that there would be statistically significant differences, indicating more illness-specific prescription medication utilization for Dentists than for Controls, especially for the older age groups (45-54) and 55-64).

1. Of the aforementioned 16/20 (80%) of instances in which Dentists were prescribed more illness-specific prescription medication than Controls, four reached statistical significance at beyond the .05 level; and also consistent with the third hypothesis, one occurred at the 35-44 age level: Neurological illnesses- 5.3% utilization (Dentists) vs. 0% utilization (Controls), with Chi-Square (d), $\chi_c^2 = 8.82$, p= 0.003. the remaining three results all occurred in the 45-54 age grouping:

2. For Neuropsychiatric medications (15.3 % utilization for Dentists as compared to 6.3% utilization for Controls, with Chi-Square (d), $\chi_c^2 = 6.25$ and p=0.012

3. For Neurological medications (7.6% utilization for Dentists compared to 1.1% for Controls, producing Chi-Square (d), $\chi_c^2 = 7.82$ and a corresponding p value of 0.005, and

4. For Combined Neuropsychological and Neurological illnesses. Here the respective utilization figures were 20.1% for Dentists and 6.3% for Controls, resulting in a Chi-Square (d), χ_c^2 value of 13.28 with a chance probability of 0.0003 or only three in 10,000.

Note: With the standard (*alpha probability (p)/* Number of Comparisons) control for Type 1 error, the adjusted *p* or Bonferroni Type 1 error (Toothaker, 1991) [30] becomes: .05/4=.0125 for each of the possible comparisons of Dentists and Controls for a given disease category, and this was reached or far exceeded for all four comparisons.

DISCUSSION

Mortality studies clearly show that the life expectancy for all white males in the Unites States has been increasing over the last 50 years. During the late 1940's the average age at death for dentists and the general population was the same at 65 years of age. The last mortality study in the United States that included dentists took place in 1972. The average age at death for a dentist was 71.5 years old, compared to 68.7 years old for the general white male population. A well-accepted reason for increased longevity is related to improved medical technology and better nutrition. Following this line of thinking dentists may have lived slightly longer in 1972 than the general population because they had the financial means to pay for better health care and a higher standard of living. The Intervention of modern medicine extends the life of those who can afford it.

Moreover, mortality studies tell us nothing about the quality of life of the living, and only give one idea of the specific cause of death. In fact, in many cases, the actual cause of death is often secondary to the major chronic illness with which the person may have been afflicted. As one example, a patient may die of cardiac arrest when the major disease process may have been emphysema.

The results of this study directly imply that for the disease categories examined, the general dentists are less healthy than matched controls. Our results, using a novel and well controlled method of data collection, namely, pharmacy utilization data, directly challenge the commonly held view of both dental practitioners and research scientists that dentists, as a more health conscious and better educated group would be healthier than age, gender, and geographically matched Controls. These results take on even more significance given that the general practice dentists and carefully matched Controls both shared in common an identical insurance plan and equivalent access to care. In addition, the data used are based on medical conditions of a magnitude that under normal

circumstances would require the patient to seek medical care. For example, a seizure disorder would be unlikely to go untreated by both the dentists and control group.

Our results are also consistent with what is known about medicine and neurotoxicity. More specifically, it is well know that the central nervous system is the critical target organ for mercury vapor, it being a strong neurotoxin (Clarkson, 1989) [45]. The neuropsychiatric category and the neurological category were also combined to determine whether there was a greater prevalence of central nervous system problems in the dentist group compared to control subjects. The finding for this combined category of 15.4% for dentists compared to 5.5% for the control group is both statistically and clinically significant. Similarly, the pure neurological, non-psychiatric category shows 6.1% pharmacy utilization of illness-specific medication by Dentists compared to only 0.8% for Controls. This implies directly that the prevalence of neurological problems among general practice dentists is 7.6 times higher than in the control group, which is a concern. Mortality studies indicate that deaths due to nervous system causes account for 9.4% of dentists deaths, of which 8.54% were due to vascular lesions (Bureau of Economic Research and Statistics, 1975) [13]. This means that the remaining causes of death for Dentists, or 0.86% are due to diseases of the nervous system. In the present study, 15.4% of dentists are suffering from some form of neurological or psychiatric problem, which is many orders of magnitude greater than 0.86%.

The poor health of dentists compared to the control group is likely due to environmental factors. While some might choose to argue that this statement is somewhat speculative, it is, in fact universally recognized that general dentists have an occupationally derived higher body burden of mercury than the general population. During the study time period, surveys indicated that 85% of general dentists both place and remove amalgam fillings (CRA Newsletter, 2001) [46]. Mercury vapor is released from the amalgam filling material upon placement and removal from teeth (Engel, *et al*., 1992; Ely. 1997; Martin, *et al*., 1995; and Pohl & Bergman, 1995) [11, 47-49]. In fact, the general dentists who do not use amalgam are still exposed to mercury vapor when they remove amalgam fillings. It is estimated that a typical dentist removes between two to ten amalgams per day (CRA, 2001) [46]. Therefore, all general practice dentists are exposed to mercury vapor whether they use amalgam or composite restorations.

What can be said for certain is that this higher mercury body burden does not make dentists healthier than the general population as some authors would prefer to believe. It would also stretch credulity to the breaking point to believe that dentists would continue to purchase illness-specific medication, to the extent that it places them in the highest category of medical health pharmacy utilization, if there were no underlying specific illnesses in need of treatment.

The major ramification of this study is that general practice dentists are at greater risk for developing certain diseases than the general population. This result was obtained using an appropriately matched control group and novel methodology heretofore not applied in research of this genre, namely, precise medical utilization information. This increases the probability that the obtained results are valid. Yet, it is of critical importance that further effort be made to clearly establish the underlying meaning of the obtained results.

Carefully designed follow-up investigations must involve permission to visit dental offices in order to measure directly and precisely both mercury exposure levels and dentist body burden, in order to correlate them with prevalence of disease.

All this said, prior studies we have reviewed and cited have obtained dental workers' mercury exposure levels and have reported findings consonant with our findings (e.g., Liang, *et al*., 1993); Meyer-Baron, *et al*., (2002); Meyer-Baron, *et al*., (2004); Shapiro, *et al*., 1996; and Uzzell & Oler, 1986 [21, 22, 33-35].

Another study that should be conducted is to compare the health of general practice dentists to other dental specialties that do not place or remove mercury fillings such as the orthodontist and the oral surgeon. This was not possible in the current investigation, due to the aforementioned restricted numbers of these specialty areas in our study population Large scale multi-site investigations, utilizing the same methodology, direct measurement of mercury levels, and a common data collection format across sites, could provide answers to this important research and clinical question.

An appropriate study investigating the effects of mercury amalgam in children has yet to be designed.

Major design flaws characterize the three clinical trials that have been recently published by Bellinger, *et al*., (2006) [37]; DeRouen, *et al*, (2006) [38]; and by Lauterbach, *et al*., (2008) [39]. In the first two studies, these included inappropriate outcome measures, such as changes in IQ between baseline and annual follow-up assessment periods, without awareness that previous studies of dentists and dental assistants exposed to mercury showed significant decrements in neuropsychological and neurological functioning, while showing no differences at all in levels of measured IQ (Uzzell & Oler, 1986 [21]; Shapiro, *et al*., 1982 [22]). It should also be mentioned that whenever IQ is used as an outcome change measure, the Bellinger, *et al* (2006) [37] stated acceptable difference of only $\pm$ 3 IQ points fails to take into account the known and confirmed larger test retest reliability change in IQ scores, even in the hands of the best and most experienced clinician (e.g., see Cicchetti, *et al*., 2004; and Kaufman, 2001 [50, 51]). It is unfortunate that researchers unfamiliar with these facts, have so incorrectly used IQ as the gold standard, both in studying the effects of low lead exposure upon children's cognitive abilities (Popock, *et al*., 1994; Schwartz, 1994 [52, 53]); and, more recently, in attempting to interpret the relationship between birth order and intelligence (Kristensen & Bjerkedal, 2007; and Sulloway, 2007 [54, 55]). Another major deficiency is that the subjects in the amalgam restoration condition, in both the Bellinger, *et al*. (2006) and the DeRouen, *et al* (2006) clinical trials [37, 38] showed extremely low levels of mercury exposure, namely, less than half the 20 µg/g defining low levels of mercury exposure (e.g., Shapiro, *et al*., 1982 [22]; Uzzell & Oler, 1986 [21]. The Lauterbach, *et al*. (2008) study [39] suffered very high subject attrition rates, with the authors making no attempt to explain their potential biasing effects.

In summary, this study demonstrates the value of pharmacy utilization as a way to evaluate the health status of a population. This method can be applied to many other areas of medicine, considering that pharmacy benefits managers administer drug plans to 186 million people in the United States. Given the statistical and clinical meaningfulness of the results, namely that dentists are much more likely to receive physician prescribed health medications that are used to treat neurological, neuropsychological, respiratory, and cardiac diseases, it would seem prudent to advise that dentists consider using restorations that do not contain mercury. This change would lead to improved medical health for themselves, their dental employees, and the children and adults they treat. To do otherwise would seem quite unwise from a world health perspective.

ACKNOWLEDGEMENTS

This research was funded by the Wallace Research Foundation. We thank Peter Sparago for specialized computer programming and help with data analysis; and to Peg Mitchell for preparing the manuscript.

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Received on 24-08-2012 Accepted on 04-09-2012 Published on 24-09-2012

http://dx.doi.org/10.6000/1929-6029.2012.01.01.01