REVIEW

Literature review of cancer mortality and incidence among dentists

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This review assesses the epidemiological literature describing dentist mortality and cancer incidence risk. In the dental workplace a variety of hazards may have been historically present or currently exist which can impact dentists' long-term health, including their mortality and cancer incidence. The epidemiological literature of dentistry's health outcomes was reviewed with a focus on all cancers combined and cancers of the brain, lung, reproductive organs and skin. Relevant studies were identified using MEDLINE and NIOSHTIC through early 2006 and from references cited in the articles obtained from these databases. Dentist cancer mortality and incidence generally showed a favourable risk pattern for lung cancer and overall cancer occurrence. Nevertheless, several studies reported an increased risk for certain cancers, such as those of the skin and, to a lesser extent, the brain and female breast. These elevated risks may be related to social status or education level, or may alternatively represent the impact of hazards in the workplace. The evidence for an increased mortality or cancer incidence risk among dentists must be interpreted in light of methodological limitations of published studies. Future studies of dentists would benefit from the assessment of specific occupational exposures rather than relying on job title alone.

and conducted meta-analyses for selected cancers to determine if the dental profession is at higher risk of developing certain cancer types as compared to the general population or individuals in other occupations. Our review focused on overall cancer risk and cancers of the brain, lung, skin, and reproductive organs. These cancer groups were selected because they were most commonly reported on in the epidemiological literature.

METHODS

Published epidemiological studies were identified through PubMed and NIOSHTIC up to June 2006 using the search phrases "Dentists"[MeSH] AND "Neoplasms"[MeSH] and "Dentists"[MeSH] AND "Mortality"[MeSH] in PubMed, and keywords "dentists and mortality", "dentists and neoplasms" and "dentists and cancer" in PubMed and NIOSHTIC. Additionally, relevant references cited in these manuscripts were retrieved. Finally, population-based case-control studies (in which cases and controls are asked about employment as a dentist at any point in their work history) and cohort studies (in which cancer mortality or incidence rates of a group of dentists are compared with those of the general population or groups of workers not employed as dentists) of the selected cancers reporting risk estimates by job title were identified and searched for risk estimates specific to dentists. Special effort was employed to limit the referenced articles to those that examined dentists only. Therefore, studies reporting on the health of a combined group of doctors, dental technicians, and/or dental assistants were excluded. Studies published in English and German were eligible for inclusion. We identified a total of 19 relevant studies (table 1). The majority of studies were identified from Medline, however, one report was not published in the peer-reviewed literature and was identified from NIOSHTIC.²⁸ For each study, we extracted the following information: authors, year of publication, country, study design, study population, duration of follow-up or time period of recruitment, outcomes studied, and covariates considered. Furthermore, statistical findings were extracted, such as standardised incidence or mortality ratios (SIR or SMR, respectively), odds ratios (OR) and rate ratios (RR).

For cancers of the brain, lung, skin, and reproductive organs overall pooled relative risk estimates of the SMR, SIR, OR and RR, and their corresponding 95% confidence intervals (CI) were obtained

The US dentist workforce currently consists of over 150 000 dentists.^{1–2} The variety of hazards in the dental workplace has been well documented, and includes exposure to infections, chemicals and radiation.^{3–11} There has been concern that exposure to these hazards may impact the health of dentists and other dental personnel, particularly exposure to mercury and ionising radiation.^{12–21} Additionally, there has been concern about the long-term health effects of exposure to dental amalgam and diagnostic x rays in patients.^{22–25} Examinations in the late 1970s indicated elevated mercury vapour levels in more than 10% of all US dental offices, which could place these office workers at a greater cancer risk if mercury is indeed carcinogenic.^{26–27} There is also strong evidence for a carcinogenic effect of ionising radiation at high doses, especially for leukaemia, but the effects of low levels of radiation exposure (including diagnostic x rays) on cancer are controversial. Surprisingly, the cancer incidence and mortality literature among dentists has not been methodically assessed despite the presence of potential carcinogens in their work environment.

We systematically reviewed cohort and case-control studies assessing dentist cancer occurrence

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Abbreviations: SIR, standardised incidence ratio; SMR, standardised mortality ratio

Table 1 Epidemiological studies of cancer mortality and incidence among dentists

First author (year)	Country	Study population	Duration of follow-up/ recruitment	Outcome	Covariates adjusted for	Comparison population†
<i>Cohort studies</i>						
Hill (1972) ⁴¹	England, Wales	1951 & 1961 England and Wales censuses (5454 male dentists)	1949–53; 1959–63	Mortality	Gender	General male population (SMR)
Omer (1976) ²⁸	US	101 351 male and 1375 female dentists	1960–5	Mortality	5-year age groups, gender, race, period	General population (SMR)
Scarrott (1978) ⁴²	England, Wales	1971 England and Wales census (11 920 male dentists)	1970–2	Mortality	Age, gender	General male population (SMR)
Walrath (1985) ^{49, 50}	US	293 958 US veterans cohort (2498 dentists)	1954–70	Mortality	Age	Entire veterans cohort (SMR)
Ahlbom (1986) ³⁷	Sweden	1960 Swedish Census Cohort (3454 male and 1125 female dentists)	1961–79	Incidence	5-year age groups, gender, county	General working population (SIR)
Preston-Martin (1989) ⁴⁷	US	Los Angeles County (8.5 million people)	1972–85	Incidence	10-year age groups, gender, race	General population (PIR)
Sankila (1990) ³⁹	Finland	1970 Finnish Census Cohort (4.6 million people)	1971–80	Incidence	Age, gender, 5-year calendar periods	General working population (SIR)
Vägerö (1990) ⁴⁴	England, Wales, Sweden	English, Welsh, and 1960 Swedish census populations (9835 melanomas)	1971–8 (E & W) 1961–79 (Sweden)	Incidence	Age (E & W); age, county of residence (Sweden)	General working population (SRR)
Linet (1995) ⁴³	Sweden	1960 Swedish male census cohort (3850 cutaneous melanoma cases)	1961–79	Incidence	5-year age groups, gender, region	General male population (SIR)
Rix (1996) ⁴⁰	Denmark	1970 Danish census cohort (13 955 male and 75 052 female healthcare workers)	1970–87	Incidence	5-year age groups, gender	General working population (SIR)
Eriksson (1998) ³⁸	Sweden	1970 Swedish census cohort (8.1 million people)	1971–84	Incidence	5-year age groups, gender, region	General population (SIR)
Shimpo (1998) ¹⁷	Japan	4704 dentists	1985–94	Mortality	10-year age groups, gender	General population (SMR)
Hostettler (2002) ⁵¹	Switzerland	4932 male and 817 female dentists	1979–92	Mortality	Age, gender	General male population (SMR)
Navas-Acién (2002) ³³	Sweden	1960 and 1970 Swedish census cohort (1 779 646 men and 1 066 346 women)	1971–89	Incidence	5-year age groups, gender, 4–5-year calendar periods, region, town size	General working population (RR)
Haldorsen (2004) ⁵²	Norway	1970 Norwegian census male cohort (893 264 men)	1971–91	Incidence	5-year age groups, smoking	12 occupational groups w/o presumed work-related lung carcinogen exposure (SIR)
Nishio (2004) ¹⁵	Japan	3314 male dentists	1964–97	Incidence	5-year age groups, gender, 5-year calendar periods	General population (SIR)
Ji (2005) ⁴⁸	Sweden	1960, 1970, 1980, 1990 Swedish censuses cohort (3.3 million men and 2.8 million women)	1961–2000	Incidence and mortality	5-year age groups, gender, 10-year calendar periods	General working population (SIR)
<i>Case-control studies</i>						
Cocco (1998) ³⁵	US	>4.5 million deaths (28 416 cases and 113 664 controls)	1984–92	Mortality	5-year age groups, gender, race, state	All other occupations (OR)
Krstev (1998) ³⁶	US	60 878 men w/prostate cancer matched w/non-cancer controls in 5/1 ratio	1984–93	Mortality	5-year age groups, race	All occupations/industries combined (MOR)

SMR, standardised mortality ratio; SIR, standardised incidence ratio; SRR, standardised rate ratio; PIR, proportionate incidence ratio; MOR, mortality odds ratio.

using fixed- and random-effects meta-analyses in the absence and presence of statistical heterogeneity, respectively.^{29–30} Study weights were equal to the inverse of the variance. The variance for SMR and SIR were determined by

$$\frac{1}{\text{Expected}}$$

where expected is the number of expected deaths or incident cases in each study. For OR and RR, the variance was computed as

$$\left[\frac{\ln(\text{UCL}) - \ln(\text{LCL})}{3.92} \right]^2$$

where LCL is the 95% lower confidence limit and UCL is the 95% upper confidence limit. Furthermore, tests for homogeneity

were performed and associated p values are reported.^{29–30} However, a limited number of studies were available for meta-analysis, and we observed statistical heterogeneity ($p < 0.20$) across studies for most cancer types evaluated. Therefore, due to the few studies available and statistical heterogeneity, our interpretation of the literature is qualitative in nature. Our focus is on point estimates reported in the original studies and their corresponding confidence interval as an indicator of precision, rather than relying on their statistical significance.³¹ Findings from proportionate mortality or incidence studies were not emphasised in our interpretation because of their known limitations.³²

RESULTS

Characteristics of published studies

The key studies discussed in this review are presented in table 1, which examined cancer mortality or incidence among dentists

Figure 1 Forest plots and random effects meta-analyses of selected types of cancer among male dentists: obs, observed number of deaths of disease cases. (A) Brain cancer (p for homogeneity=0.02); (B) lung cancer (p for homogeneity=0.0; Eriksson *et al*³⁸ not included because of overlap with other study populations); (C) prostate cancer (p for homogeneity=0.0); (D) melanoma (p for homogeneity=0.7; Linet *et al*⁴³ not included because of overlap with other study populations).

in Denmark, England and Wales, Finland, Japan, Sweden, Switzerland, and the US. The dentist populations' cancer risks (SIR) were primarily evaluated by establishing a cohort of dentists based on a national census, with many studies relying heavily on the 1960 and 1970 census data, and determining cancer incidence using national cancer registry. Death certificate analysis was the next most used information source to determine SMRs. The SIR or SMR were generally calculated using either the general population or the employed population as the reference. Typically, these studies controlled for age groupings and gender, but rarely accounted for occupational exposure or socioeconomic status. Some studies did include an occupational exposure component, but often the exposures were too broad in scope and did not specifically address the potential dentistry occupational hazards.^{33–35} The two case-control studies listed in table 1 used death certificate data collected from 24 US states and matched cases with non-cancer controls to determine odds ratios.^{35–36} The relative risk estimates reported in the original studies for the cancer types of interest along with the meta-analytical findings are presented in figures 1 and 2.

Cancer incidence epidemiological studies

Overall cancer

Most of the epidemiological studies suggest that dentists are either at an average or decreased risk for neoplasms. Two

Swedish cohorts, based on the 1960 and 1970 population censuses, had a dentist cancer rate near the population average (males: SIR 1.0, CI 0.9 to 1.2; females: SIR 1.0, CI 0.8 to 1.2, and total: SIR 1.1, CI 1.0 to 1.2).^{37–38} These findings agreed with a Finnish report on female dentists (SIR 1.1, CI 0.8 to 1.5)³⁹ and the findings of a Denmark study with a 17 year follow-up.⁴⁰ In a US 1960s cohort, a reduced risk for each gender was determined (males: SMR 0.7, CI 0.7 to 0.8; females: SMR 0.5, CI 0.3 to 0.9),²⁸ which is similar to both the England and Wales cohort data for male dentists (1949–53, 1959–63: SMR 0.8, CI 0.6 to 0.9 and 1970–2: SMR 0.6, CI 0.4 to 0.9)^{41–42} and a Finnish report on male dentists (SIR 0.5, CI 0.2 to 1.1).³⁹ Only a Japanese study clearly suggested an increased male dentist neoplasm risk (SMR 1.4, CI 1.2 to 1.5).¹⁷

The reported variability in cancer risk may indicate geographic variations in dentist occupational risk in developed countries, possibly because of differences in workplace exposures and practices. Alternatively, the time period of the studies could be a factor as the cohorts with a decreased or normal cancer risk were primarily from the 1960s and 1970s, whereas the Japanese study followed a population from 1985–94.

Brain cancer

Several studies have reported on dentist brain cancer risk, predominantly in Scandinavia^{33–34 37–40 43–44} and the US.^{45–47} Examinations of brain cancer in Swedish dental personnel

Figure 2 Forest plots and random effects meta-analyses of selected types of cancer among female dentists: obs = observed number of deaths of disease cases. (A) Brain cancer (p for homogeneity = 0.1); (B) lung cancer (p for homogeneity = 0.6; Eriksson *et al*³⁸ not included because of overlap with other study populations); (C) breast cancer (p for homogeneity = 0.0); (D) melanoma (p for homogeneity = 0.9).

used the 1960 and 1970 censuses to define their population samples.^{33–34, 37–38, 48} Based on follow-up through 1979, dentists showed a 2–2.5-fold increased risk of glioblastoma and glioma.³⁷ Dentists followed through 1984 were found to have an increased central nervous system cancer risk in men (SIR 1.6, CI 0.8 to 2.7) but not women (SIR 0.6, CI 0.0 to 2.2).³⁸ A Swedish cohort study with follow-up through 1989 also found about a twofold elevated risk of glioma in male dentists.^{33–34}

US cancer incidence studies have been less conclusive and complete. A proportionate incidence study reported an increased risk of glioma (PIR 1.7, CI 0.5 to 4.4) and meningioma (PIR 3.8, CI 0.5 to 13.9) separately and for all histological types of brain cancer combined (PIR 2.5, CI 1.1 to 4.7) among white male dentists between the ages 25 and 64.⁴⁷ Additionally, a US death certificate case-control study reported increased central nervous system cancer risks.³⁵ Conversely, two recent US population-based case-control studies found little evidence for an increased brain cancer risk associated with work as either a dentist or dental technician^{45–46} (data not presented). Additionally, no increased brain cancer risk was found in two US 1960s male dentist cohorts (SMR 0.9, CI 0.6 to 1.2 and SMR 0.6, CI 0.1 to 1.8).^{28–29, 50}

These results are somewhat suggestive of an increased brain cancer risk in male dentists (pooled RR 1.5, CI 1.0 to 2.0), especially in Swedish studies.^{33–37, 38} However, the Swedish findings cannot necessarily be viewed independently (see Discussion) and may not be generalisable to other countries.

Furthermore, the data are too sparse to provide more definitive conclusions.

Lung cancer

Most epidemiological studies consistently suggest that lung and respiratory cancer risk was decreased (RR ~0.5–0.7) in male dentists in England and Wales,⁴¹ Sweden,^{38–48} Switzerland,⁵¹ the US,²⁸ and Norway; the Norwegian study adjusted for the effects of smoking.⁵² Furthermore, no cancers of the lung were found in a Finnish male dentist cohort.³⁹ In contrast, two recent investigations of Japanese male dentists did not observe a decreased lung cancer risk but rather found that the dentists' risk was similar (SIR 1.0, CI 0.7 to 1.4)¹⁵ or slightly elevated (SMR 1.3, CI 1.0 to 1.7)¹⁷ to that of the general population.

Findings for female dentists suggested lung cancer rates close to expected as calculated in a Swedish study with a follow-up from 1971–84,³⁸ a Swedish study examining dentists from 1961–2000,⁴⁸ and the 1960s US cohort.²⁸

Overall, these data do not suggest that dentists have increased lung cancer rates. On the contrary, male dentists appear to have a reduced lung cancer risk (pooled RR 0.6, CI 0.5 to 0.8), which may not be surprising as dentists have one of the lowest smoking rates compared with other occupational groups.^{53–58}

Reproductive cancer

There is some indication for an increased risk of cancer of the reproductive organs among male and female dentists, again

Table 2 Percentage of dental specialties in the US dentist workforce

Specialty	1960s ¹²	1991 ^{2*}	1998 ^{2*}	Responsibility ^{62, 63}
General dentistry	94.6	79.4	79.4	Diagnoses and treats teeth and gums
Orthodontist	2.0	5.9	5.8	Straightens teeth
Oral and maxillofacial surgeon	1.1	4.2	4.0	Diagnoses and surgically repairs injuries, defects and diseases of mouth and jaws
Endodontist	—†	2.0	2.3	Deals with the morphology, physiology, pathology, aetiology, diagnosis, prevention and treatment of diseases of the pulpal and periapical tissues
Paediatric dentist	0.2	2.4	2.5	Diagnoses and treats children
Prosthodontist	0.2	2.2	2.0	Makes artificial teeth and dentures
Periodontist	0.3	2.9	3.0	Deals with prevention, diagnosis, treatment and maintenance of the supporting structures of the teeth using preventive, surgical and nonsurgical techniques
Public health dentist	0.0	0.8	0.7	Deals with public preventive education, community treatment programs and applied dental research
Oral pathologist	0.0	0.3	0.2	Studies oral disease
Other	1.6	—†	—†	Not previously listed

*Includes private practitioner, dental school faculty or staff, armed forces dentist, government-employed dentist, graduate student, intern or resident, or other health and dental organisation staff member.²

†Not reported.

mostly based on the Scandinavian studies. Danish male dentists in private clinics were at an increased risk for testicular cancer (SIR 3.0, CI 1.1 to 6.4), while salaried female dentists showed an excess breast cancer risk (SIR 1.6, CI 1.1 to 2.4)⁴⁰ The risk of female breast cancer among dentists was also somewhat higher in a Finnish examinations of Finnish and Swedish healthcare workers (SIR 1.4 to 1.5)^{38, 39} although our meta-analysis does not suggest an increased risk (pooled RR 1.0, CI 0.5 to 1.9) due to a reduced breast cancer mortality risk in an early study.

Epidemiological findings of prostate cancer among dentists do not suggest an increased risk (pooled RR 1.0, CI 0.8 to 1.3). A Swedish cohort study and a US case-control trial showed a small increased prostate cancer risk (RR 1.2 to 1.3).^{36, 38} In contrast, the Temple study depicted a reduced prostate cancer risk (SMR 0.8, CI 0.7 to 1.0)²⁸ and a Switzerland cohort examination found a near average risk (SMR 1.1, CI 0.3 to 2.7).⁵¹

The cancer data listed above are not strongly indicative of any positive or negative trend for increased dentist reproductive cancer incidence, with the possible exception of female breast cancer. However, the data are too sparse to draw any firm conclusions regarding the risk of reproductive cancers among dentists.

Skin cancer

Several Scandinavian and UK cohort studies of dentists reported an increased skin cancer risk. A 19-year follow-up study of Swedish men employed in the 1960 census found a 2.1–2.2-fold increased risk for cutaneous melanoma compared with the general Swedish male population.^{43, 44} A later Swedish study with five additional follow-up years supported these findings and reported a significantly 2.3-fold increased risk of epithelial skin cancer and melanoma among male and female dentists.³⁸ A cohort study combining England, Wales, and Sweden cancer registration data observed a similarly increased malignant cutaneous melanoma risk among dentists.⁴⁴ Continuing this trend, Rix and Lynge reported high skin cancer rates in Danish male dentists in private clinics (melanoma: SIR 3.0, CI 1.3 to 5.8 and other skin: SIR 1.7, CI 1.1 to 2.4).⁴⁰

The Scandinavian and UK cohort studies consistently illustrated that dentists of these countries are at a roughly twofold increased risk of developing some form of skin cancer (men: pooled RR 2.4, CI 1.6 to 3.7; women: pooled RR 2.0, CI 1.1 to 3.9).^{38, 40, 43, 44} It is possible that this increased skin cancer occurrence is more influenced by socioeconomic status than it is by a work-related exposure because higher rates have been reported for a variety of white-collar professional groups.^{40, 43, 44}

DISCUSSION

Although several cohort studies reported increased cancer risk for brain, skin, and some reproductive cancers in dentists, there are certain methodological limitations that should be taken into account (see below). These limitations, along with some interstudy procedural variations involving reference populations and controls, may complicate establishing dentists' cancer mortality and incidence risks.

Significantly, most of the epidemiological studies in table 1 simply examined incidence or mortality rates and did not make a thorough attempt to document potential work-related exposures. This dearth of exposure-response studies on dentist cancer incidence and mortality makes it difficult to directly attribute evident increased cancer risks to occupational exposure. This is especially pertinent when numerous other factors possibly influencing the health outcomes (that is, confounders) may have been present but were not accounted for in the statistical analysis.

Another key consideration and an ongoing debate is whether exposure to a variety of hazards such as infections, chemicals found in dental fillings and aesthetic gases, and radiation due to x ray exposure significantly impacts a dentist's health.^{12–21} It has been argued that the implementation of protective measures (for example, gloves, masks, ventilation) and careful work practices in the US and other developed countries over the past decades has minimised any dentistry employment health risk,^{9, 59} but it is uncertain if this is also true in developing countries. Dentist mortality studies have generally shown a favourable risk pattern, but several studies have demonstrated an increased risk of specific cancers, including malignant melanoma, brain, and female breast cancers. These findings may be due to factors related to dentists' higher social status and education levels,⁵⁹ but do not rule out an impact of workplace exposures on dentists' health.

Risk inconsistencies across studies may result from differences in study design, duration of follow-up, calendar period, or geographic location. Many of the increased cancer risks were observed solely in Scandinavian studies that may not be representative of the cancer risk in the US or other locations, as a result of possible geographic variation in exposures and work practices. Also, studies with a limited duration of follow-up,²⁸ including some cohort examinations in the UK⁴² and US,²⁸ cannot sufficiently consider the often long latency period between initiation of exposure and subsequent health effects.⁶⁰

Including only studies that examined dentists as a unique subgroup provided some measure of consistency between the studies. Most of the studies reviewed here, however, relied on a single job title that did not consider the variety of exposure

Main messages

- Most epidemiological studies report a normal or decreased risk of dentist cancer mortality and incidence in regards to lung and total neoplasm rates.
- Some studies suggest that dentists may have an elevated risk for brain, skin and some reproductive cancers.
- Important study limitations hinder ascertaining dentistry's occupational risk, including a failure to assess exposure-response relationships, possible geographical or temporal variation in cancer risk, and the lack of control for socioeconomic status and related behavioural factors.

levels and work environments within the dentistry profession. For example, the American Dental Association has historically recognised eight specialties, although general dentistry has predominated (table 2). Job tasks and exposure to different substances may vary across specialties or perhaps private practices within a country and between countries. The lack of consideration of exposure variability on cancer risk may have masked increased disease risks, if any, associated with specific exposures in the various dental workplaces. Also, the lack of increased cancer risk may be due to the healthy worker effect, although this is thought to be less important in the interpretation of cancer mortality and incidence.⁶¹ Finally, the interpretation of results based on job title only is limited by possible confounding of non-occupational factors (for example, behavioural or socioeconomic factors) that are related to both employment and disease, which is particularly a concern in cohort studies comparing disease rates among dentists to disease rates in the general population.

A final cautionary note is that significant portions of the data in the Swedish studies were present from one study to the next. Thus, it is not appropriate to view the findings from these studies as independent observations, because they all use a similar population sample.^{33 37 38} Consequently, not as many data may be available as it seems, and there exists a need for further evaluation of dentists' health.

CONCLUSION

Epidemiological examinations of dentist mortality and cancer incidence have typically shown a normal or decreased risk pattern for lung and overall neoplasm occurrence. Several studies reported an increased risk for cancers of the skin and, to a lesser extent, of the brain and some reproductive organs. The reasons for these increased risks are unknown and may be related to workplace exposure or social status and education level. In light of conflicting findings and methodological limitations of published studies, we conclude that there is presently little evidence to suggest a work-related increase in cancer risk among dentists.

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