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Journal of the Formosan Medical Association (2012) 111, 567–571

Available online at www.sciencedirect.com

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ORIGINAL ARTICLE

# Mortality among dentists in Taiwan, 1985–2009

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Received 3 May 2011; received in revised form 12 June 2011; accepted 14 June 2011

**KEYWORDS**
Cox proportional hazard model;
dentist;
mortality;
standardized mortality ratios (SMRs)

*Background/Purpose:* Controversy exists in the literature regarding whether dentists with multiple occupational exposures suffer from premature mortality. A cohort mortality study was conducted to evaluate the survival outcome and determine if potential exposure to harmful agents leads to premature mortality among dentists.
*Methods:* Using the Life Table Analysis System, we calculated standardized mortality ratios (SMRs) for a cohort of 11,700 dentists affiliated with the Taiwan Dental Association. These dentists were followed from 1985–2009. Reference rates were derived from cause-, gender-, and age-specific mortality rates of the general population of Taiwan and 18,664 Taiwanese internists, who were considered to be more socioeconomically proximal to dentists. A Cox proportional hazard model was also constructed to determine multiple risk factors associated with mortality.
*Results:* Compared with the general population, dentists in Taiwan consistently demonstrated reduced from all-cause mortality. However, compared with internists, significant and excess mortality were observed in dentists for overall mortality (SMR = 1.13; 95% confidence interval [CI] = 1.00–1.26), drowning (SMR = 6.62; 95% CI = 2.15–15.45), and heart diseases (SMR = 1.66; 95% CI = 1.22–2.21). After adjusting for other risk factors, the Cox model showed an increased hazard ratio of 1.17 (95% CI = 1.01–1.37) for dentists.
*Conclusion:* Taiwanese dentists demonstrated significant elevated SMRs for overall causes, drowning, and heart diseases. Careful precaution should be taken to reduce these trends. Future studies are also needed for in-depth exploration of the mechanisms regarding how professional stress and exposure contribute to the increased risk of mortality in Taiwanese dentists.


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0929-6646/$ - see front matter 
doi:10.1016/j.jfma.2011.06.010

## Introduction

Dentists are potentially exposed to hazardous chemicals and physical and biological agents such as amalgams, anesthetics, noise, vibration, radiation, and viruses.[1–5] Notably, dentists are at increased risk of exposure to hepatitis B virus and the human immunodeficiency virus (HIV),[6] of which the potential routes of exposure include sharp injuries and body fluid exchange.[7,8] Furthermore, dentists are subjected to severe stress, burnout, substance abuse, and commit suicide at a higher rate, at least among healthcare professionals.[9–11]

There are also studies[12,13] that have reported the increased relative risks of dentists to develop cancers of the brain, lung, and reproductive organs, in addition to increased combined all-cancer mortality. These elevated risks might represent the impact of the potential hazards in the workplace; however, the relationship between the mortality rate of dentists and hazardous agents has not been clearly elaborated. As the risk of death from cancer increases with advanced age, the assessment of true cancer risks requires longer periods of follow-up examinations. In order to improve the validity of the abovementioned studies, additional socioeconomically comparable reference groups should be recruited and the duration of the follow-up examinations must be extended to detect any increase in mortality.

In this study, a cohort was established through the dentist registry file of the Taiwan Dental Association (TDA). Dentists were included who joined the association in 1985 and were followed through 2009. They were compared with internists recruited from the Taiwan Medical Association (TMA) to evaluate survival outcome and to determine if the abovementioned potential exposure to harmful agents leads to premature mortality among dentists.

## Participants and methods

The study was approved by the ethical review board of National Taiwan University. The registry file of the TDA provided the basic demographic information of the study cohort, which was initiated in January 1985 and terminated at the end of December 2009. Information included the name, date and place of birth, gender, personal identification (ID) number, enrollment, education, medical specialties, location of practice, vital status, date of death, and date of termination of membership or retirement of each individual. The termination of practice was defined as the end of the study, date of death, or termination of membership. There were 410 participants for whom we were unable to find the date of license acquisition, which were assumed to be July 1 of the year the dentist turned 24 years of age.

The causes of death were obtained from the National Mortality Registry (NMR) at the Department of Health, Taiwan through the ID number of each deceased individual. Twenty-six of the 289 deceased dentists had an unknown cause of death. The all-cause and cause-specific mortality rates of the dentists were compared with those of the reference groups. Person-years and standardized mortality ratios (SMRs) were calculated using the Life Table Analysis System (LTAS.NET), which was first developed by the National Institute for Occupational Safety and Health (NIOSH), and SMRs and 95% confidence intervals (CIs) were calculated using the mortality rates of the 119 underlying causes of death of the general population and internists of Taiwan as the reference group, respectively. In this study, we set the significance level to $p < 0.05$. While the mortality rates of the general population can be directly retrieved from the vital statistics tables of Taiwan, we recruited similar data on all practicing internists in the TMA. These individuals were followed from 1990–2006 to serve as an alternative reference group.[14]

Cox proportional hazard analysis was conducted to determine the hazard ratios and 95% CIs for the following risk factors: age, gender, specialty, geographic region of practice, age at the beginning of practice, year practice was begun (before or after 1995 when the NHI system was established), and physician-to-population ratio. The physician-to-population ratios were categorized into four levels: $>$ 1:500, between 1:500 and 1:700, between 1:700 and 1:900, and $<$ 1:900 (Table 1). We applied a stepwise strategy for variable selection using a significance level for entry and significance level to stay that were both set to 0.15. Regression diagnostics were also run, including examination of the proportional hazard assumption, residual analysis, and detection of influential cases, and we also checked for multicollinearity to assure good quality analysis and goodness of fit of the model.

## Results

A total of 11,700 dentists with 207,831.11 person-years were accrued until December 31, 2009, when the follow-up examinations were terminated. During this period, 289 members died. By the time of the censored date, December 31, 2006, 18,664 internists with 963,791.51 person-years were included in this study.

The basic demographic data of the study participants are summarized in Table 1.The gender ratio of the participants was 3.25:1 (male:female), which is lower than that of the internists. More than half (53.2%) of the dentists practiced in the northern region, and 47.8% of the subjects were registered in areas with high physician-to-population ratios. About two-thirds of the subjects initiated their practice before 1995 and over 90% began to practice dentistry before the age of 30.

The observed number of deaths and cause-specific SMRs for dentists are summarized in Table 2. Nearly all of the SMRs of dentists are $<$ 0.5 when compared with the general population of Taiwan. The crude death rate of the internists was higher than that of dentists (6.4% vs. 2.5%; Table 1), but this discrepancy disappeared after adjusting for age, gender, and the calendar year of beginning practice (Table 2). When we applied a socioeconomically more comparable population—the internists—as a reference group, the overall SMR of the dentists significantly increased (SMR = 1.13; 95% CI = 1.00–1.26) and the SMR of drowning was 6.62 with a 95% CI ranging from 2.15–15.45 (Table 2). Dentists were also more likely to die from heart diseases (SMR = 1.66; 95% CI = 1.22–2.21). The SMRs of malignant neoplasm and cerebral vascular disease were

**Table 1** Demographic characteristics of dentists and internists in Taiwan.

| | Dentists | | Internists | |
|---|---|---|---|---|
| | No. (%) | Mean censored age (y) | No. (%) | Mean censored age (y) |
| Total | 11,700 (100) | 44.77 ± 12.01 | 18,664 (100) | 48.90 ± 15.94 |
| Status | | | | |
| Alive | 11,411 (97.5) | 44.31 ± 11.49 | 17474 (93.6) | 44.31 ± 11.49 |
| Deceased | 289 (2.5) | 62.81 ± 17.38 | 1190 (6.4) | 71.92 ± 12.70 |
| Sex | | | | |
| Male | 8945 (76.5) | 46.79 ± 11.86 | 16,693 (89.4) | 50.16 ± 15.99 |
| Female | 2755 (23.6) | 38.19 ± 10.00 | 1971 (10.6) | 38.33 ± 10.78 |
| Age at the beginning of practice (y) | | | | |
| < 30 | 10,640 (90.9) | 44.01 ± 11.80 | 13533 (72.5) | 44.05 ± 12.63 |
| 30 ≤ age < 40 | 971 (8.3) | 51.32 ± 10.65 | 3205 (17.3) | 53.79 ± 14.68 |
| ≥ 40 | 89 (0.8) | 69.53 ± 13.91 | 1926 (10.3) | 74.92 ± 10.09 |
| Region | | | | |
| Northern | 6224 (53.2) | 44.36 ± 12.03 | 8744 (46.8) | 48.14 ± 16.03 |
| Central | 2279 (19.5) | 45.29 ± 12.12 | 3494 (18.7) | 48.33 ± 15.10 |
| Southern | 3008 (25.7) | 44.96 ± 11.91 | 5905 (31.6) | 50.36 ± 16.23 |
| Eastern | 189 (1.6) | 48.72 ± 10.87 | 521 (2.8) | 49.25 ± 15.63 |
| Physician-population ratio | | | | |
| > 1:500 | 5590 (47.8) | 45.27 ± 12.33 | 7796 (41.8) | 46.83 ± 15.68 |
| 1:700 to 1:500 | 1667 (14.2) | 44.05 ± 11.42 | 3313 (17.8) | 48.58 ± 16.41 |
| 1:900 to 1:700 | 1860 (15.9) | 45.60 ± 12.21 | 5995 (32.1) | 50.48 ± 15.61 |
| < 1:900 | 2583 (22.1) | 43.53 ± 11.42 | 1560 (8.4) | 53.98 ± 15.73 |
| Years of practice | | | | |
| Before 1995 | 7292 (62.3) | 52.07 ± 8.62 | 12510 (67.0) | 56.46 ± 13.84 |
| After 1995 | 4408 (37.7) | 32.69 ± 5.12 | 6154 (33.0) | 33.56 ± 5.46 |

marginally increased, although they did not reach a statistically significant level. We did not detect any significant increase in the SMRs for suicide, accidents, chronic obstructive pulmonary disease, pneumonia/influenza, HIV-related diseases, or liver cirrhosis.

To further adjust for other risk factors among dentists and internists, a Cox proportional hazard model was constructed and the results are summarized in Table 3. Using the internists as the referents, the dentists appeared to show a higher overall hazard ratio of 1.17 (95% CI = 1.01−1.37).

## Discussion

To the best of our knowledge, this is the first nationwide study to be performed on the long-term mortality of dentists. The dentists actually demonstrated a significantly lower SMR than the general population after adjusting for age, gender, and time spent practicing. Additionally, the SMR for major causes of mortality were nearly all well below 0.5, as showed in Table 2. The lower overall mortality rate of Taiwanese dentists in comparison with the general population may be partially attributed to the healthy worker effect (HWE) phenomenon, which is the tendency of the actively employed to live longer than the population at large. HWE has been reported to reduce the association between exposure and clinical outcome by a magnitude of 20−30%.[15,16] In our study, the SMRs for mortality among Taiwanese dentists were < 0.5, which might imply a continued accumulation of professional knowledge, similar to Taiwanese physicians.

However, a misleading conclusion might have been generated by using the general population as the reference group because of the higher socioeconomic status of dentists, which appears to be similar to physicians.[17] To control such a potentially confounding factor, we adopted internists as the reference population for SMR calculation and found significantly increased SMRs (1.13, 6.62, and 1.66, respectively) for overall causes, drowning, and heart diseases (Table 2). After adjusting for additional risk factors through the construction of a Cox proportional hazard model, the dentists still showed a higher hazard ratio of 1.17 (95% CI = 1.01−1.37) in comparison with internists (Table 3), indicating a consistent trend. In other words, the younger average age of the deceased dentists than that of the deceased internists might be partially attributed to their premature mortality after adjustment for age, gender, and other risk factors.

The elevated SMRs of dentists in Taiwan were found in terms of heart diseases, including ischemic heart diseases and hypertension, which corroborate the hypothesis of increased stress proposed by some investigators.[9,11,18,19] Different from reports on other countries,[20,21] dentists in Taiwan demonstrated similar SMRs (1.45, 95% CI = 0.58−2.99) for suicide compared with internists. Our study also

**Table 2** Observed number of deaths and cause-specific standardized mortality ratios (SMRs) with confidence intervals (CI) for dentists using internists and the general population of Taiwan as reference groups.

| Reference group | | Internists | General population |
|---|---|---|---|
| Causes of death | No. observed | SMR (95% CI) | SMR (95% CI) |
| All causes | 289 | 1.13 (1.00—1.26) | 0.31 (0.28—0.35) |
| All MN | 96 | 1.16 (0.94—1.41) | 0.42 (0.34—0.51) |
| MN of digestive organs and peritoneum | 50 | 1.03 (0.77—1.36) | 0.41 (0.31—0.54) |
| MN of respiratory system | 20 | 1.33 (0.82—2.06) | 0.56 (0.34—0.86) |
| MN of urinary organs | 5 | 1.63(0.53—3.81) | 0.99 (0.32—2.31) |
| MN of lymphatic and hematopoietic tissue | 7 | 1.04 (0.42—2.15) | 0.55 (0.22—1.13) |
| MN of other and unspecified sites | 8 | 1.69 (0.73—3.34) | 0.69 (0.30—1.37) |
| Cerebrovascular disease | 26 | 1.50 (0.98—2.20) | 0.35 (0.23—0.52) |
| Heart disease | 47 | 1.66 (1.22—2.21) | 0.70 (0.51—0.93) |
| Ischemic heart disease | 28 | 1.65 (1.10—2.39) | 0.90 (0.60—1.30) |
| Conductive disorder | 1 | 1.34 (0.03—7.47) | 0.25 (0.01—1.41) |
| Hypertension with heart disease | 6 | 10.55 (3.87—22.96) | 7.05 (2.59—15.35) |
| Diabetes mellitus | 5 | 0.60 (0.19—1.39) | 0.16 (0.05—0.37) |
| Chronic liver disease | 9 | 1.23 (0.56— 2.34) | 0.12 (0.06— 0.23) |
| Kidney disease | 3 | 0.87 (0.18—2.53) | 0.23 (0.05—0.67) |
| Pneumonia | 3 | 0.29 (0.06—0.86) | 0.18 (0.04—0.52) |
| Chronic lung disease | 4 | 2.18 (0.60—5.59) | 0.39 (0.11—0.99) |
| Transportation injuries | 13 | 0.87 (0.46—1.49) | 0.15 (0.08—0.25) |
| Fall | 1 | 0.47 (0.01—2.59) | 0.06 (0.00—0.32) |
| Other injury | 10 | 1.19 (0.57—2.19) | 0.16 (0.08—0.29) |
| Drowning | 5 | 6.62 (2.15—15.45) | 0.36 (0.12—0.84) |
| Suicide | 7 | 1.45 (0.58—2.99) | 0.16 (0.06—0.33) |

MN = malignant neoplasm.

found five dentists who died of drowning and a higher cause-specific SMR (6.62, 95% CI = 2.15—15.45) for dentists compared with internists. Deaths by drowning are generally suspected of being suicides. As a sensitivity analysis, we reclassified all nontraffic-related deaths, including drowning deaths, as suicides; however, the SMR did not significantly increase. Thus, we tentatively conclude the possibility of miscoding or misclassifying suicides as accidental injuries as unlikely. Based on our qualitative enquiry, many dentists pursue fishing as a hobby, especially in the ocean surrounding Taiwan. The unexpected tides and weather conditions might partially explain the increased SMR of drowning by dentists, and careful precautions should be taken to reduce this risk.

**Table 3** Hazard ratios and confidence intervals (CI) estimated from the Cox regression model of the mortality rates of dentists and internists in Taiwan.

| Covariate | Hazard ratio | 95% CI | *p* |
|---|---|---|---|
| Age of beginning practice | | | |
| | 1.12 | 1.11—1.13 | < 0.0001 |
| Sex | | | |
| Female/Male | 0.84 | 0.62—1.15 | 0.2753 |
| Specialty | | | |
| Dentist/Internists | 1.17 | 1.01—1.37 | 0.0405 |
| Region | | | |
| Central/Northern | 1.12 | 0.97—1.30 | 0.1355 |
| Southern/Northern | 1.27 | 1.13—1.43 | < 0.0001 |
| Eastern/Northern | 1.48 | 1.09—2.00 | 0.0120 |
| Physician-population ratio | | | |
| 1:700 to 1:500/ > 1:500 | 1.22 | 1.04—1.42 | 0.0120 |
| 1:900 to 1:700/ > 1:500 | 1.18 | 1.04—1.34 | 0.0088 |
| < 1:900/ > 1:500 | 1.10 | 0.92—1.31 | 0.2988 |
| First year of practice | | | |
| After/before 1995 | 3.20 | 1.87—5.48 | <0.0001 |

There are several limitations of this study. First, the exact dates of obtaining the dentist license were absent for 410 out of 11,700 members. Most of these participants were very old and began their practices before 1985. We determined the time spent practicing dentistry from the date of obtaining the license through December 31, 2009 or the date of death or termination of membership. For those with incomplete information on the date or month of obtaining the license, we assumed the date to be July 1 of the year the dentist turned 24 years of age because most dentists graduate from dental schools around this time. Thus, we might have slightly overestimated the time spent practicing dentistry, which could result in the underestimation of the risk of mortality. But, this assumption might not affect the overall conclusion. Second, because the follow-up periods of two cohorts of dentists and internists were different, namely 1985—2009 and 1990—2006, respectively, this raises concerns regarding comparability and potential bias. However, because there were no catastrophic events (such as an epidemic of severe acute respiratory syndrome or earthquakes larger than 6.0—7.0 on the Richter magnitude

scale, etc.) in Taiwan during both periods, the likelihood of potential bias may be minimal. Third, the analyses did not incorporate information regarding the levels of the clinics and hospitals being practiced. Thus, we had to assume that it might be a random effect that only lead to underestimation or had a null effect.

In conclusion, Taiwanese dentists demonstrated significantly elevated SMRs for overall causes of death, drowning, and heart diseases (particularly ischemic heart diseases and hypertension) compared with internists, and careful precautions should be taken to reduce these trends. Future studies are also needed for in-depth exploration of the mechanisms that affect how professional stress contributes to these increased mortality risks in Taiwanese dentists.

## Acknowledgments

The authors wish to thank the Taiwan Dentist Association and Taiwan Medical Association for providing the original data and for their generous support of this investigation. The study was partially supported by a grant from the National Science Council of the Executive Yuan, Taiwan (no. NSC 99-2628-B-006-036-MY3).

## References

1. Mandel ID. Occupational risks in dentistry: comforts and concerns. *J Am Dent Assoc* 1993;**124**(10):40—9.
2. Brownawell AM, Berent S, Brent RL, Bruckner JV, Doull J, Gershwin EM, et al. The potential adverse health effects of dental amalgam. *Toxicol Rev* 2005;**24**(1):1—10.
3. Babich S, Burakoff RP. Occupational hazards of dentistry: a review of literature from 1990. *NY State Dent J* 1997;**63**: 26—31.
4. Perrone J. Doctors, nurses, and dentists. In: Greenberg MI, Hamilton RM, Phillips SD, McCluskey GJ, editors. *Occupational, industrial, and environmental toxicology* 2003. p. 88—95.
5. Torbica N, Krstev S. World at work: dental laboratory technicians. *Occup Environ Med* 2006;**63**:145—8.
6. Eli I, Capilouto Milton C, Weinsteirm, David H, Deborah C. What is the dentist's occupational risk of becoming infected with hepatitis B or the human immunodeficiency virus? *Am J Public Health* 1992;**82**:587—9.
7. Palmer GD, Fleming GJ. The management of occupational exposures to blood and saliva in dental practice. *Dent Update* 2000;**27**(7):318—24.
8. Webber LM. Bloodborne viruses and occupational exposure in the dental setting. *SADJ* 2000;**55**(9):494—6.
9. Rada RE, Johnson-Leong C. Stress, burnout, anxiety and depression among dentists. *J Am Dent Assoc* 2004;**135**(6): 788—94.
10. Gorter RC, Storm MK, te Brake JH, Kersten HW, Eijkman MA. Outcome of career expectancies and early professional burnout among newly qualified dentists. *Int Dent J* 2007;**57**(4): 279—85.
11. Wilson B. Stress in dentistry: national survey. *Dent Management* 1984;**24**:14—9.
12. Simning A, van Wijngaarden E. Literature review of cancer mortality and incidence among dentists. *Occup Environ Med* 2007;**64**:432—8.
13. Shimpo H, Yokoyama E, Tsurumaki K. Causes of death and life expectancies among dentists. *Int Dent J* 1998;**48**:563—70.
14. Shang TF, Chen PC, Wang JD. Mortality of doctors in Taiwan, 1990-2006 [published online ahead of pint October 21, 2010]. *Occup Med (Lond)* 2010.
15. McMichael AJ. Standardised mortality ratios and the "healthy worker effect" : scratching beneath the surface. *J Occup Med* 1976;**18**:165—8.
16. Last J. *A dictionary of epidemiology*. 3rd ed. Oxford, UK: Oxford University Press; 1995.
17. Wang JD, Miettinen OS. Occupational mortality studies: principles of validity. *Scand J Work Environ Health* 1982;**8**:153—8.
18. Fisher S. *Stress in academic life: the mental assembly line*. Buckingham: Society for Research Into Higher Education and The Open University Press; 1994.
19. Alexander RE. Stress-related suicide by dentists and other health care workers Fact or folklore? *J Am Dent Assoc* 2001; **132**(6):786—94.
20. Stack S. Suicide risk among dentists: a multivariate analysis. *Deviant Behav* 1996;**17**:107—18.
21. Petersen MR, Burnett CA. The suicide mortality of working physicians and dentists. *Occup Med (Lond)* 2008;**58**(1):25—9.