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Cigarette smoking and tooth loss in a cohort of older Australians

The 45 and Up Study

Manish Arora, PhD; Eli Schwarz, PhD; Shanti Sivaneswaran, MDS; Emily Banks, PhD

Oral health is an integral part of systemic health.¹ Poor oral health directly affects quality of life and has been linked to a number of systemic disorders, including cardiovascular disease and cancer, as well as preterm deliveries and an increased likelihood of having low-birth-weight infants.²⁻⁹ The causes of tooth loss are multifactorial and include numerous sociodemographic and lifestyle factors.

In Australia, as in many industrialized nations, tooth loss is more prevalent among those in the lower educational and income strata and among those who lack dental insurance.¹⁰ Indigenous Australians and those residing in remote rural regions also experience more tooth loss than do Australians living in urban centers. Although the prevalence of tooth loss continues to decline, a large proportion of older Australians still experience a complete loss of all natural teeth. Approximately 14 percent of Australians aged 55 to 75 years are edentulous, and the proportion increases to 36 percent in those 75 years and older.¹⁰ Apart from differences within sociodemographic groups, tooth loss also has been linked to lifestyle factors such as tobacco smoking.^{11,12}

Tobacco smoking is widely recognized as one of the most significant modifiable risk factors for oral dis-

ABSTRACT

Background. Data regarding the long-term effects of smoking, smoking cessation and environmental tobacco smoke (ETS) on tooth loss are limited.

Methods. The authors collected information about tooth loss and other health-related characteristics from a questionnaire administered to 103,042 participants in the 45 and Up Study conducted in New South Wales, Australia. The authors used logistic regression analyses to determine associations of cigarette smoking history and ETS with edentulism, and they adjusted for age, sex, income and education.

Results. Current and former smokers had significantly higher odds of experiencing edentulism compared with never smokers (prevalence odds ratio [OR], 2.51; 95 percent confidence interval [CI], 2.31-2.73 and OR, 1.50; 95 percent CI, 1.43-1.58, respectively). Among former smokers, the risk declined significantly with increasing time since smoking cessation; however, the risk remained elevated even in those who ceased smoking 30 or more years previously compared with that in never smokers (OR, 1.10; 95 percent CI, 1.02-1.19). Furthermore, among never smokers, the OR for edentulism was 1.37 (95 percent CI, 1.17-1.60) in those who reported having exposure to ETS for six or more hours per week versus those who were not exposed to any ETS.

Conclusions and Clinical Implications. Although the risk of experiencing tooth loss declines with time since smoking cessation, the effects of smoking may persist for at least 30 years. The effect of ETS requires further investigation.

Key Words. Tooth loss; cigarette smoking; environmental tobacco smoke.

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eases, including periodontitis and dental caries, that can lead to tooth loss.¹³ In a study examining the relationship of tooth loss to current smoking and smoking cessation, Dietrich and colleagues¹² found a persistent increased risk for at least 10 years after participants stopped smoking. Data for longer periods after smoking cessation are scarce, and evidence regarding the possible effect of environmental tobacco smoke (ETS) on tooth loss is limited.

The purpose of this study was to investigate detailed aspects of the relationship between edentulism and self-reported cigarette smoking, long-term smoking cessation and exposure to ETS in approximately 100,000 Australians 45 years and older.

PARTICIPANTS AND METHODS

Study participants. A detailed description of the 45 and Up Study cohort has been described elsewhere.¹⁴ Briefly, the 45 and Up Study is a large-scale Australian cohort study of people 45 years and older that began in 2006 and is aimed at providing timely and reliable information about a wide range of exposures and outcomes of public health importance for the aging population. In addition to addressing specific research questions, the study is designed as a framework for a range of future research activities. Investigators in the 45 and Up Study have recruited more than 250,000 participants 45 years and older from the general population of New South Wales, Australia. The study investigators randomly sampled eligible people from Australia's Medicare enrollment database and mailed them study enrollment material and a study questionnaire. The researchers oversampled people 80 years and older and those who lived in rural areas. Participants joined the study by returning a completed questionnaire and a signed consent form.

In our study, we used cross-sectional baseline questionnaire data from the first 103,042 eligible participants; data from the full cohort are not yet available. Of these 103,042 participants, 99,663 responded to the question about tooth loss. The Human Research Ethics Committee of The University of New South Wales, Sydney, Australia, provided ethical approval for the 45 and Up Study.

Classification of variables. We obtained data regarding all but one variable from the baseline self-reported questionnaire; the one exception

was region of residence, which we determined from the respondent's post code (ZIP code) recorded in the Medicare Australia database. We determined edentulism from participants' responses to this question: "How many of your own teeth do you have left?" There were four possible responses:

- none—all of my teeth are missing;
- one to nine teeth left;
- 10 to 19 teeth left;
- 20 or more teeth left.

We categorized as edentulous the participants who reported that they had no teeth remaining.

We used responses to the question "Have you ever been a regular smoker?" to define participants as smokers or never smokers. Smokers were asked on the questionnaire to record the age at which they started smoking, the number of cigarettes smoked on average each day and, if they were no longer smoking, their age when they stopped smoking regularly. We based categories of smoking intensity (one to 14, 15-24 and 25 or more cigarettes per day) on a study by Doll and colleagues¹⁵ of cigarette smoking and mortality. We based categories of time since last use of cigarettes and duration of smoking on the distributions in the 45 and Up Study data set, which were designed to maximize study power for examining relative associations within each group. In addition, participants recorded the number of hours per week they were exposed to someone else's tobacco smoke at home and elsewhere.

The main sociodemographic variables used in the multivariable adjusted analyses were sex; age (in years); Aboriginal or Torres Strait Islander status; primary language spoken at home (English versus other); highest educational attainment (no school certificate [did not finish 10th grade], school or intermediate certificate [completed 10th grade], higher school certificate [completed 12th grade], trade or apprenticeship [vocational training], certificate or diploma [for example, technician] or university degree); and household pretax annual income (in Australian dollars). We classified alcohol intake as the number of drinks consumed per week (ranging from none to greater than 40 drinks). We calculated body mass index (BMI) from self-reported height and weight and categorized it as lower than 20, 20 to 24.9, 25 to

ABBREVIATION KEY. BMI: Body mass index. ETS: Environmental tobacco smoke.

29.9 or 30 or higher.

Statistical analysis. We examined the distribution of cigarette smoking according to potential confounding factors, as well as within categories of tooth loss. We grouped participants into those who had no teeth versus those with some teeth. For analyses involving cigarette smoking, we classified participants as current, former or never smokers. Among former smokers, we estimated the odds of being edentulous within categories of years since smoking cessation (< 10, 10-19, 20-29, 30 or more). In this analysis, we classified heavy smokers (20 or more cigarettes per day) separately from those who smoked fewer than 20 cigarettes per day. In addition, we examined the odds of experiencing tooth loss within categories of smoking intensity in both current and former smokers. Similarly, we compared participants who reported having smoked for 50 or more years with those who smoked for 35 to 49 years and those who smoked for less than 35 years.

We used multivariable adjusted logistic regression analyses to estimate the odds ratio (OR) for the association between smoking variables and tooth loss. We included age (in years), sex, educational attainment and income as covariates. We also introduced multiplicative terms (such as age × smoking variable) into the logistic regression analyses to determine if there were any statistically significant interactions between key characteristics (age, sex, income, education and Aboriginal and Torres Strait Islander status) and smoking variables.

We conducted sensitivity analyses to assess whether adjusting for additional covariates—including alcohol consumption, region of residence¹⁶ (major city, inner regional, outer regional, remote and very remote), Aboriginal or Torres Strait Islander status and BMI—resulted in any appreciable change in the association between smoking variables and tooth loss. Inclusion of these variables produced only minor (< 10 percent) changes in the parameter estimates of the smoking variables. Consequently, to retain the most parsimonious model, we excluded these additional variables from the logistic regression analyses. Furthermore, to examine the differences between the OR (estimated from logistic regression analyses) and prevalence risk ratios

(RRs), we conducted a sensitivity analysis by using Poisson regression models with robust variance estimation to measure the RR for the association between smoking characteristics and tooth loss. We conducted all statistical analyses by using statistical software (SAS version 9.1, SAS Institute, Cary, N.C.).

RESULTS

Of the 99,663 respondents who answered the tooth loss question, 51,915 (52.1 percent) were female and 47,748 (47.9 percent) were male. Participants ranged in age from 44.7 to 106.2 years, with a mean age of 63.1 years. With regard to the number of teeth remaining, participants' responses were as follows: no teeth, 10,037 (10.1 percent); one to nine teeth, 10,613 (10.6 percent); 10 to 19 teeth, 20,281 (20.3 percent); and 20 or more teeth, 58,732 (58.9 percent).

When we classified participants as being edentulous or as having some teeth remaining, clear differences were evident with regard to sociodemographic categories. Notably, complete tooth loss was more common in women, in those

identifying themselves as Aboriginal or Torres Strait Islanders and in those who spoke languages other than English at home. We also observed a statistically significant difference between educational categories (3.1 percent of participants with university degrees reported being edentulous compared with 23.1 percent of those who had not earned a school certificate [that is, 10th grade]) and between income categories (2.0 percent of participants in the highest income group reported being edentulous versus 20.4 percent of those in the lowest income group [$P < .001$]). However, we should note that these results were not age adjusted and are meant to be an indication of potential confounding only.

Table 1 shows participants' characteristics according to smoking status. Women were more likely than men to be never smokers and less likely to be heavy former smokers (that is, 20 or more pack-years). A considerably smaller proportion of those in the highest income strata (\$70,000 or more per year [about \$62,000 in American dollars]) and those with a university education reported being current or former heavy smokers (20 or more pack-years). Edentulism was more

Complete tooth loss was more common in women, in those identifying themselves as Aboriginal or Torres Strait Islanders and in those who spoke languages other than English at home.

TABLE 1

Characteristics of participants in the 45 and Up Study, according to smoking status (N = 99,663*).

CHARACTERISTIC	NO. (PERCENT) OF PARTICIPANTS†				
	Never Smokers	Former Smokers		Current Smokers	
		Less than 20 pack-years	20 pack-years or more	Less than 20 pack-years	20 pack-years or more
Male	23,427 (40.3)	9,817 (51.0)	10,481 (68.2)	609 (38.4)	2,743 (50.2)
Mean (SD‡) Age in Years	63.2 (11.3)	62.1 (11.2)	66.2 (10.6)	54.7 (8.0)	58.6 (8.9)
Aboriginal or Torres Strait Islander	347 (0.6)	133 (0.7)	156 (1.0)	28 (1.8)	133 (2.4)
University Educated	14,633 (25.2)	4,779 (24.8)	2,226 (14.5)	308 (19.4)	587 (10.8)
Annual Income \$70,000 or More in Australian Dollars	13,413 (23.1)	5,148 (22.9)	2,341 (15.2)	332 (20.8)	726 (13.3)
Reside in Major City	26,152 (45.0)	8,289 (43.1)	6,187 (40.3)	663 (41.8)	2,045 (37.5)
Possess Health Care Concession Card	15,136 (30.7)	4,647 (28.9)	5,640 (44.6)	407 (35.9)	2,118 (53.8)
Consume 21 or More Alcoholic Drinks per Week	2,265 (3.9)	1,906 (9.9)	2,483 (16.2)	156 (9.8)	878 (16.1)
Body Mass Index of 30 or Higher	10,711 (18.4)	3,622 (18.8)	4,149 (27.0)	279 (17.6)	1,078 (19.7)
Edentulous	4,898 (8.7)	1,429 (7.7)	2,381 (16.0)	97 (6.4)	791 (15.1)

* Totals do not equal 99,663 because of missing data.
† Unless otherwise specified.
‡ SD: Standard deviation.

common among current and former smokers who reported a smoking history of 20 pack-years or more (Table 1).

Time since smoking cessation. Compared with the OR for never smokers, the OR for edentulism was 2.51 (95 percent confidence interval [CI], 2.31-2.73) in current smokers and 1.50 (95 percent CI, 1.43-1.58) in former smokers after we adjusted for age, sex, income and education (Table 2). Time since smoking cessation was inversely associated with the odds of having experienced complete tooth loss ($P[\text{trend}] < .002$) (Table 2). In former smokers who smoked 20 or more cigarettes per day, the odds of having experienced complete tooth loss remained elevated even 30 years after quitting. Former smokers who smoked fewer than 20 cigarettes per day exhibited comparatively lower odds of having experienced tooth loss and were no longer at an elevated risk 30 years after quitting. The results showed no significant interaction between time since cessation and the number of cigarettes smoked per day ($P[\text{interaction}] < .77$).

Smoking intensity. In both current and former smokers, the intensity of smoking, as measured by the number of cigarettes smoked per day, was associated positively with the odds of experiencing tooth loss (Table 3, page 1247). Current

smokers who smoked 25 or more cigarettes per day had the greatest odds of having experienced tooth loss. Former smokers who had quit within 20 years of the study and had smoked more than 25 cigarettes per day exhibited a similar association.

Smoking duration. The duration of smoking also was positively associated with the odds of being edentulous (Table 4, page 1247). Current smokers who had been smoking for 50 years or longer were at 169 percent higher odds of having experienced complete tooth loss compared with never smokers. The increase in odds was significantly lower among former smokers who had smoked for a similar period before quitting.

The effect of current and former smoking on edentulism did not differ significantly according to participant's age, sex, education, income or Aboriginal or Torres Strait Islander status (data not shown). Results of the Poisson regression analyses showed that, as expected, the RRs generally were smaller than the ORs; however, these differences were on the order of 17 percent or less, indicating that the ORs were not a gross overestimation of the risk of experiencing tooth loss associated with smoking.

ETS exposure. Exposure to ETS was a significant predictor of complete tooth loss in smokers (current and former) and nonsmokers. In never

TABLE 2

Prevalence odds ratio of edentulism in relation to time since participants quit smoking.*				
YEARS SINCE SMOKING CESSATION	NO. OF CASES/ POPULATION	ODDS RATIO (95% CI†)	P FOR TREND	
Never Smokers	4,898/56,203	1.00	< .002	
Current Smokers	939/7,230	2.51 (2.31-2.73)		
All Former Smokers				
< 10	719/6,382	2.06 (1.88-2.26)		
10-19	820/7,112	1.80 (1.65-1.96)		
20-29	946/9,157	1.54 (1.42-1.66)		
≥ 30	1,221/9,717	1.10 (1.02-1.19)		
Former Smokers (< 20 Cigarettes per Day)				< .001
< 10	240/2,611	1.68 (1.46-1.95)		
10-19	253/2,904	1.35 (1.17-1.55)		
20-29	392/4,621	1.26 (1.12-1.42)		
≥ 30	690/5,809	1.00 (0.92-1.10)		
Former Smokers (≥ 20 Cigarettes per Day)			< .001	
< 10	479/3,780	2.31 (2.07-2.57)		
10-19	567/4,222	2.11 (1.91-2.34)		
20-29	554/4,566	1.82 (1.64-2.01)		
≥ 30	531/3,967	1.30 (1.17-1.44)		

* The odds ratios were adjusted for age, sex, income and education.
 † CI: Confidence interval.
 ‡ The square sizes are inversely proportional to the variance of the log odds ratio, indicating the amount of statistical information available.

smokers, the ORs for complete tooth loss were 1.22 (95 percent CI, 1.10-1.36) for participants reporting exposure to someone else’s tobacco smoke for one to five hours per week and 1.37 (95 percent CI, 1.17-1.60) for those reporting exposure to secondhand smoke for six or more hours per week, compared with the ORs for those reporting no exposure, after we adjusted for age, sex, income and education (*P*[trend] < .001).

DISCUSSION

In this study of approximately 100,000 older Australians, smoking was a significant predictor of tooth loss, with both current and former smokers being at significantly greater risk compared with never smokers. Although smoking cessation appeared to be beneficial, former smokers remained at an elevated risk of losing all of their teeth even 30 years after quitting.

Among current smokers, the odds of losing all teeth increased progressively with the number of cigarettes smoked per day. The odds of edentulism in those who smoked 25 or more cigarettes per day were almost three times as high as those

in nonsmokers. We observed a similar pattern in former smokers—the greater the number of cigarettes smoked per day, the greater the risk of experiencing complete tooth loss. Smoking duration also was a significant predictor of edentulism. Participants who smoked for a longer period were at the highest risk of experiencing tooth loss, and this pattern persisted among both current and former smokers after we adjusted for the effects of age and sociodemographic factors.

The beneficial effect of smoking cessation was clear, as former smokers had lower odds of experiencing tooth loss compared with current smokers. However, among former smokers who had smoked 20 or more cigarettes per day, the odds of experiencing tooth loss remained somewhat elevated even 30 years after quitting. Among former smokers who smoked fewer than 20 cigarettes per day, the odds declined to those for nonsmokers only after 30 years, indicating that the effects of cigarette smoking persist for decades.

Exposure to secondhand smoke produced a modest but significant increase in the risk of experiencing tooth loss, even among those who had

TABLE 3

Prevalence odds ratio of edentulism in relation to intensity of smoking.*				
SMOKING INTENSITY	NO. OF CASES/POPULATION	ODDS RATIO (95% CI†)		P FOR TREND
Never Smokers	4,898/56,203	1.00		
Current Smokers, No. of Cigarettes per Day				
1-14	274/2,185	2.23 (1.93-2.56)		.003
15-24	356/2,797	2.38 (2.10-2.70)		
≥ 25	270/1,902	2.84 (2.47-3.28)		
All Former Smokers, No. of Cigarettes per Day				
1-14	1,240/12,682	1.15 (1.07-1.23)		< .001
15-24	1,436/13,234	1.51 (1.41-1.61)		
≥ 25	1,194/8,009	2.16 (2.00-2.33)		
Former Smokers Who Quit Less Than 20 Years Previously, No. of Cigarettes per Day				
1-14	375/4,172	1.48 (1.31-1.66)		< .001
15-24	597/5,583	1.81 (1.64-2.00)		
≥ 25	670/4,557	2.47 (2.24-2.71)		
Former Smokers Who Quit 20 or More Years Previously, No. of Cigarettes per Day				
1-14	863/8,504	1.03 (0.95-1.12)		< .001
15-24	838/7,645	1.32 (1.21-1.44)		
≥ 25	523/3,441	1.80 (1.62-2.01)		

* The odds ratios were adjusted for age, sex, income and education.
 † CI: Confidence interval.
 ‡ The square sizes are inversely proportional to the variance of the log odds ratio, indicating the amount of statistical information available.

TABLE 4

Prevalence odds ratio of edentulism in relation to smoking duration.*				
SMOKING DURATION (YEARS)	NO. OF CASES/POPULATION	ODDS RATIO (95% CI†)		P FOR TREND
Never Smokers	4,898/56,203	1.00		
Current Smokers				
< 35	123/2,371	1.76 (1.45-2.14)		.001
35-49	489/3,759	2.56 (2.30-2.85)		
≥ 50	312/981	2.69 (2.33-3.11)		
Former Smokers				
< 35	193/6,601	1.25 (1.07-1.46)		< .001
35-49	1,227/16,543	1.46 (1.36-1.57)		
≥ 50	2,643/12,160	1.55 (1.46-1.64)		

* The odds ratios were adjusted for age, sex, income and education.
 † CI: Confidence interval.
 ‡ The square sizes are inversely proportional to the variance of the log odds ratio, indicating the amount of statistical information available.

never smoked. Although we observed this finding after adjusting for a range of factors, we cannot exclude the possibility of residual confounding.

Our findings regarding the effects of active smoking are consistent with those reported in a

prospective study of male health care professionals, in whom an elevated risk resulting from smoking was evident for more than 10 years after quitting.¹² In that cohort, as in this study, the risk of experiencing tooth loss declined with

increasing time since smoking cessation. In our study, however, we could examine the effect of smoking cessation across a longer period (> 30 years) because of the large sample that included older participants who had given up smoking many years previously.

The findings reported in our study also are supported by biological mechanisms linking tobacco smoking with tooth loss. Cigarette smoking is known to disrupt the host immune-inflammatory response to bacterial pathogens, resulting in impaired wound healing and increased breakdown of periodontal tissues.¹⁷ As a result, cigarette smoking increases the risk of developing periodontal disease, which can lead to tooth loss.^{18,19} Cigarette smoking also increases the risk of developing dental caries,^{20,21} which is another important cause of tooth loss. ETS was associated with edentulism in our study. This finding is consistent with that of increased tooth loss among smokers, but it requires confirmation from other studies, preferably including prospective data regarding ETS.

The 45 and Up Study had a response rate of 18 percent, which is similar to that of other population-based cohort studies. Although the 45 and Up Study was not designed as a prevalence survey, the proportion of participants with edentulism (10.1 percent) is in broad agreement with data presented in a report by the New South Wales chief health officer.²² In that survey of New South Wales residents 55 years and older, rates of edentulism ranged from 6.3 percent in men and 7.4 percent in women aged 55 to 64 years to 19.0 percent in men and 33.3 percent in women 75 years and older. The results of our study also are similar to those of The National Survey of Adult Oral Health,¹⁰ in which investigators reported that 13.9 percent of Australians aged 55 to 75 years were edentulous. The prevalence of smoking in the 45 and Up Study cohort is, as expected, lower than that in the general population. However, ORs calculated by using internal comparisons from 45 and Up Study data—including ORs relating to smoking—agree well with ORs examining the same relationships calculated by using more representative data.²³ Hence, the findings reported here should be generalizable to the broader population.

Sociodemographic and lifestyle factors. In this study, the proportion of participants with complete tooth loss varied considerably within different sociodemographic and lifestyle categories.

Women were more likely to report experiencing complete tooth loss than were men. Although such sex differences have been observed in adult Australians and populations elsewhere, the reasons for this finding are unclear.^{10,24-26} Hugo and colleagues²⁷ proposed that greater sensitivity to their own dental needs and use of intervention-type dental services may be responsible for the higher tooth loss in women. Hormonal factors and osteoporosis also may play a role in tooth loss.²⁸ Educational attainment and income are well-established determinants of tooth loss, and the lower proportion of edentulous participants in the higher educational and income categories in our study agrees with the results of several other studies.^{10,29-31}

Study limitations. When interpreting the results of this study, one should keep in mind that older participants lived during the time when caries prevalence was at its height and exposure to fluoridated drinking water was low.³² The levels of tooth loss observed, therefore, may reflect the frequent reliance on tooth extractions as a means of treating carious lesions. Our study is limited primarily by its cross-sectional design and, consequently, we were unable to establish a temporal relationship between sociodemographic and lifestyle factors and tooth loss. In addition, the observed associations may be biased as a result of unmeasured confounders.

Study strengths. Our study is strengthened by a large number of participants spanning a wide age range with varying smoking histories. In addition, we recorded the details of a number of other potential risk factors, including ETS.

Self-reports of tooth loss. We determined the complete absence of teeth on the basis of participants' self-reports; clinical examinations were not conducted. A number of studies, however, have shown that self-reports of tooth loss are in agreement with the results of clinical examinations.³³⁻³⁵ In a prospective study comparing semiannual self-reports with biannual clinical oral examination results across a four-year period, Gilbert and colleagues³⁵ reported excellent agreement between self-reported tooth loss and clinical examination findings. When assessing tooth loss as a binary outcome (that is, some tooth loss versus none), the authors³⁵ found an agreement (Cohen κ) of 0.88.

CONCLUSIONS

The results of our study show that cigarette smoking is an important risk factor for tooth loss.

Current smokers were at more than twice the risk of experiencing complete tooth loss compared with never smokers. Moreover, although there appear to be clear benefits of smoking cessation, the elevated risk attributable to smoking persisted for several decades, especially in heavy smokers. Prospective investigations are needed to confirm the associations reported in this study. If confirmed, the findings regarding ETS have important public health implications, in that ETS is a readily modifiable cause of tooth loss. ■

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