

# Tobacco smoking and tooth loss in adults and elderly in Brazil: a populational-based cross-sectional study

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**Objectives:** To determine the association between smoking and tooth loss in individuals aged 18 years or more living in Brazil. **Methods:** Secondary analysis of the 2019 Brazilian National Health Survey data. The outcome was self-reported tooth loss, and the main independent variable was tobacco smoking. Family income, schooling, sex and age were covariates. Multiple linear regression analysis determined the association between tobacco smoking and the number of missing teeth and then the average number of missing teeth was predicted according to smoking status. **Results:** The mean number of missing teeth in 88,531 individuals aged 18 or more was 7.7 (95%CI: 7.6-7.8). At least one missing tooth was identified in 72.0% (95%CI: 71.4-72.6) of the population, 21.3% (95%CI: 20.9-21.7) had a non-functional dentition, 14.2% (95%CI: 13.9-14.6) had severe tooth loss and 10.3% (95%CI: 10.0-10.6) were edentulous. The adjusted regression coefficients for number of missing teeth showed that current or former smokers, individuals with low family income and schooling, older age and females exhibited higher tooth loss. Current and former smokers had 1.40 (95%CI: 1.35-1.46) and 1.13 (95%CI: 0.54-0.98) times more lost teeth than never smokers, respectively. **Conclusions:** Both tooth loss and smoking are common in Brazilians and are associated. Unfavorable socioeconomic status and demographic factors also predict tooth loss.

**Keywords:** Social Determinants of Health, Tooth loss, Tobacco smoking, Health surveys

## Introduction

Tooth loss is a cumulative event in extent and prevalence, which reflects a lifetime of dental diseases and treatments (Kassebaum *et al.*, 2014). It is considered a public health problem that leads to loss of functionality, pain and suffering, with a substantial impact on quality of life and years lived with disability (GBD, 2017).

Tooth loss is monitored in many countries. Although a significant reduction in severe tooth loss (less than 9 natural teeth in the mouth) has been observed in high-income countries since the 1990s, it remains common in some countries, such as Brazil (Kassebaum *et al.*, 2014). The 2010 Brazilian national oral health survey revealed an average of 7.4 missing teeth in adults (35-44 years) and an edentulism rate of approximately 54% among the elderly (65-74 years) (Peres *et al.*, 2013).

Dental caries and periodontitis, the most prevalent oral diseases, are the main causes of tooth loss (Helal *et al.*, 2019). Socioeconomic conditions, such as income and schooling, and health-related behaviors, such as smoking and dental health services utilization, are also determinants of tooth loss (Peres *et al.*, 2013; Ribeiro *et al.*, 2016; Nico *et al.*, 2016). Tooth loss is an expression of social inequalities, occurring in a social gradient. Globally, low income and schooling are systematically associated with tooth loss (Seerig *et al.*, 2015), which has also been observed in Brazilian national health surveys (Peres *et al.*, 2013; Nico *et al.*, 2016).

Tobacco smoking is also associated with tooth loss (Tonetti *et al.*, 2018; Helal *et al.*, 2019). Individuals

who smoke are more prone to lose teeth than those who have never smoked (Alharthi *et al.*, 2019), with a dose-dependent association (Souto *et al.*, 2019). The risk decreases after smoking cessation but may remain for up to 20 years (Dietrich *et al.*, 2015). The most plausible biological explanation for tooth loss in smokers is the destruction of supporting periodontal tissues. The dysregulation of the immune response to bacterial threat leads to periodontal damage, with progressive loss of attachment (Leite *et al.*, 2018). The predictability and effectiveness of periodontal treatments are also reduced among smokers (Chaffee *et al.*, 2021).

Although the global prevalence of smoking has reduced substantially in the last 30 years, the number of smokers remains high – with an increase of 0.99 billion people since 1990. In Brazil, since 1989, the National Tobacco Control Program has combined efforts and initiatives to control tobacco use and reduced smoking around seventy percent by 2019 (GBD, 2021).

Tobacco smoking used to be more prevalent in high-income countries. However, a decline in consumption in these countries has been observed. In contrast, smoking in low- and middle-income countries has shown a notable increase (Chaffee *et al.*, 2021). As with tooth loss, smoking is also socially patterned (Allen *et al.*, 2017) with vulnerable social groups having higher smoking rates (Dietrich *et al.*, 2015; Cornelius *et al.*, 2020; Wang *et al.*, 2018).

Although the association between smoking and tooth loss is known, there are still important motivations to investigate it. This includes unbiased population estimates

on tooth loss according to smoking status, considering the role of the main confounding factors. Additionally, population-based health surveys provide consistent information about health conditions and have been increasingly used to assess reported morbidity, health-related behaviors, and health services organization, to support the strengthening of public policies. In this context, this study aimed to determine the association between smoking and tooth loss among Brazilian adults and elderly using nationwide health survey data, considering the effect of demographic characteristics and socioeconomic status on this relationship.

## Methods

We analyzed secondary data from the 2019 Brazilian National Health Survey (NHS), a national household-based cross-sectional survey, carried out by the Brazilian Institute of Geography and Statistics (IBGE), in partnership with the Ministry of Health. The NHS study population was obtained through a probabilistic sample of household clusters, selected from the Master Sample for household surveys, defined based on the 2010 Demographic Census, which corresponds to a set of primary sampling units (PSUs) (census tracts) selected to serve several surveys of the Brazilian Integrated System of Household Surveys carried out by the IBGE (Szwarcwald *et al.*, 2014).

The 2019 NHS is representative for Brazil, Major Regions, Federation Units, metropolitan regions, and State capitals. Sampling was conducted in three stages: 1st, selection with probability proportional to size of PSUs in each Master Sample strata; 2nd, simple random sampling selection of households within each PSU; 3rd, simple random sampling selection of one household resident, aged 15 or over. For this study, data from selected dwellers aged 18 or over were analyzed ( $n=88,531$ ).

The sample size for the NHS was calculated using prevalence estimates of the outcomes of interest, with 95% confidence level, at the different strata of geographic disaggregation, the design effect, the number of households selected per PSU, and the proportion of households with individuals in the age group of interest, along with a non-response rate of 20%.

Our study outcome was self-reported tooth loss. The main independent variable was smoking. The other explanatory variables were age, sex and socioeconomic status, characterized by family income and schooling. Questions from 2019 NHS were used to measure these variables (<https://www.pns.icict.fiocruz.br/wp-content/uploads/2021/02/Questionario-PNS-2019.pdf>). Self-reported tooth loss was measured using the following items: “Thinking about your upper permanent teeth, have you lost any?” and “Thinking about your permanent lower teeth, have you lost any?”. The answer options were: 1, No; 2, Yes, I lost \_\_\_ teeth; 3, Yes, I lost all my teeth.

Items enquired about smoking cigarettes or other tobacco products. Participants were classified according to CDC definitions, as current smoker (everyday smoker and someday smoker), former smoker and never smoker. An adult who had smoked at least 100 cigarettes or equivalent in her/his lifetime, and who now smokes every day was classified as an ‘everyday smoker’. Those who did not smoke every day were classified as a ‘someday smoker’.

‘Former smokers’ were adults who had smoked at least 100 cigarettes over their lifetime but had quit smoking at the time of interview. ‘Never smokers’ had smoked less than 100 cigarettes in their lifetime.

Socioeconomic status was measured by education and monthly family income. Schooling was calculated by the years of study completed with approval. Family income corresponded to the sum of earnings from salaries and benefits (in Brazilian reais, R\$). Data on household asset ownership were also used. Demographic variables included sex, age, and race/skin color (white, black, Asiatic, brown, and indigenous).

First, a descriptive analysis estimated populational parameters. A non-functional dentition was defined as less than 21 remaining natural teeth. Severe tooth loss was considered as less than nine remaining teeth, while edentulism was the loss of all the teeth (non-mutually exclusive categories) (Kassebaum *et al.*, 2014; Laguzzi *et al.*, 2016). The number of remaining natural teeth was calculated by subtracting the number of missing teeth from 32. Then, zero-inflated negative binomial regression analysis determined the association between smoking status and the number of missing teeth with exponentiated regression coefficients and their respective 95% confidence intervals (95%CI), adjusted for socioeconomic and demographic variables. The average number of missing teeth was predicted by smoking status using the *margins* post-estimation command. Finally, the estimates were calculated by region of the country and ‘socioeconomic status’, defined for each geographic stratum using principal component analysis including the variables family income, schooling and number of household assets. The quintiles of the predicted scores of the socioeconomic status component were used to estimate the number of missing teeth. All the analyses were carried out in the software Stata SE, version 17, considering the complex sampling design and sampling weights (*svy* command).

This study used secondary data in the public domain. The 2019 NHS project was approved by the National Research Ethics Commission, report No. 3,529,376.

## Results

The Brazilian population aged 18 or over presented an estimated average number of missing teeth of 7.7 (95%CI: 7.6-7.8). The prevalence of loss of at least one tooth, non-functional dentition, severe tooth loss and edentulism was 72.0% (95%CI: 71.4-72.6), 21.3% (95%CI: 20.9-21.7), 14.2% (95%CI: 13.9-14.6) and 10.3% (95%CI: 10.0-10.6), respectively. Adults classified as never smoker were 73.8% (95%CI: 73.3-74.3), 9.3% (95%CI: 8.9-9.6) were current smokers (every or some days) and 17.0% (95%CI: 16.6-17.4) were former smokers. Table 1 presents the characterization of the study population. Estimates of tooth loss according to smoking status are presented in Table 2.

Current and former smokers, adults who were of lower socioeconomic status, older or female had higher tooth loss. Socioeconomic and demographic variables also predicted the absence of tooth loss (inflated model). Current smokers had 1.40 (95%CI: 1.35-1.46) times more missing teeth and former smokers 1.13 (95%CI:

**Table 1.** Characteristics of 88,531 adult and elderly Brazilians.

Variable	Estimate	95%CI
Sex, %		
Male	46.8	-
Female	53.2	-
Age, mean	44.9	44.9-45.0
Race/Skin color, %		
White	43.3	42.6-44.0
Black	11.5	11.1-11.9
Asiatic	0.9	0.8-1.1
Brown	43.8	43.1-44.5
Indigenous	0.5	0.5-0.6
Years of study, %		
None	6.1	5.9-6.4
1 to 7 years	25.3	24.8-25.9
8 to 14 years	48.8	48.1-49.4
15 years or more	19.8	19.1-20.5
Familiar income, %		
Until 1 minimum wage	45.0	44.4-45.6
2 to 3 minimum wages	37.9	37.3-38.6
More than 3 minimum wages	17.1	16.5-17.7
Smoking status, %		
Never smoker	73.8	73.3-74.3
Former smoker	17.0	16.6-17.4
Someday smoker	0.6	0.5-0.7
Everyday smoker	8.6	8.3-9.0

95%CI not reported for sex due to poststratification  
 Minimum wage = 998.00 Brazilian Real (at the time of the survey)

**Table 2.** Self-reported missing teeth by smoking status, Brazil, 2019.

Smoking status	Number of missing teeth (mean, 95%CI)	Non-functional dentition (%; 95%CI)	Severe tooth loss (%; 95%CI)	Edentulism (%; 95%CI)
Never smoker	5.9 (5.8-6.0)	15.4 (15.0-15.8)	10.2 (9.9-10.5)	7.5 (7.2-7.8)
Former smoker	11.2 (10.8-11.5)	33.6 (32.3-34.8)	22.6 (21.5-23.6)	15.6 (14.7-16.6)
Current smoker	11.2 (10.8-11.6)	33.8 (32.1-35.5)	22.8 (21.4-24.2)	16.4 (15.3-17.8)

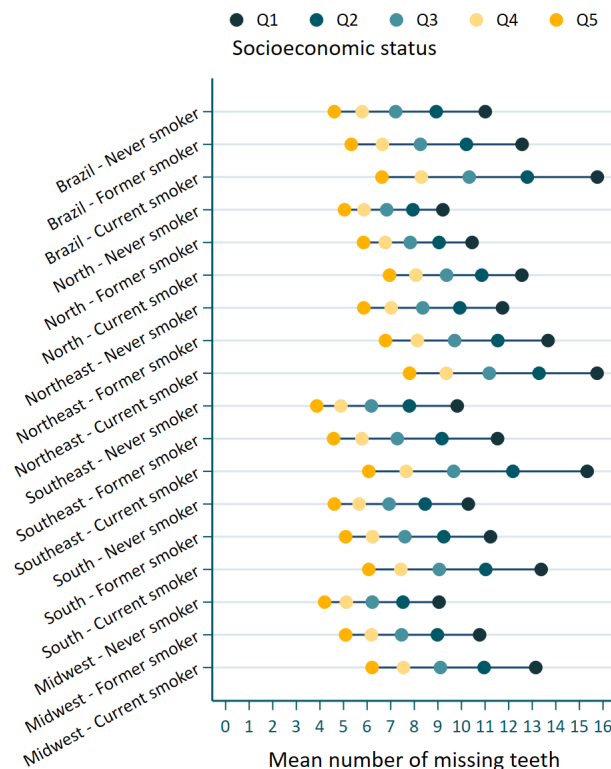
1.10-1.17) times more than never smokers, adjusted for the other covariates (Table 3). Post-estimation of the average number of missing teeth, adjusted for the other covariates, is presented in Table 4, showing significant differences in the number of missing teeth by smoking status. Figure 1 presents the estimates for the Brazilian regions, according to the smoking status and quintiles of socioeconomic status. It shows the effect of smoking on tooth loss regardless the geographic region and socioeconomic status.

**Table 3.** Zero-inflated negative binomial multiple regression model for predictors of the number of missing teeth.

Variable	IRR	95%CI
<i>Count outcome</i>		
Smoking status (ref.: never smoker)		
Former smoker	1.13	1.10-1.17
Current smoker	1.40	1.35-1.46
Family income (log R\$)	0.90	0.88-0.91
Years of study	0.95	0.95-0.95
Age	1.04	1.04-1.05
Female sex (ref.: male)	1.21	1.17-1.24
<i>Inflat</i>		
PR		
95%CI		
Smoking status (ref.: never smoker)		
Former smoker	0.90	0.81-0.99
Current smoker	0.98	0.88-1.09
Family income (log R\$)	1.17	1.12-1.23
Years of study	1.05	1.04-1.06
Age	0.95	0.95-0.96
Female sex (ref.: male)	0.90	0.84-0.95

**Table 4.** Predicted values for number of missing teeth adjusted for socioeconomic and demographic variables.

Smoking status	No. missing teeth Mean (95%CI)
Never smoker	7.5 (7.3-7.6)
Former smoker	8.5 (8.3-8.8)
Current smoker	10.5 (10.1-10.9)



**Figure 1.** Mean number of missing teeth by smoking status, geographic region and socioeconomic status.

## Discussion

Current smokers had more missing teeth than former smokers and those who never smoked. Former smokers had more missing teeth than never smokers. In addition, higher family income and schooling were associated with lower tooth loss, while increasing age and being female were associated with higher tooth loss. Self-reported tooth loss was common among Brazilian adults and elderly people, and just over a third of this population reported current or past daily smoking.

The mean number of missing teeth among current smokers was 10.5, among former smokers was 8.5, and 7.5 among never smokers. Other studies have identified this association (Tonetti *et al.*, 2018; Alharthi *et al.*, 2019; Helal *et al.*, 2019), as a dose-dependent association between smoking and tooth loss, with greater the daily consumption or duration of smoking, related to more tooth loss (Dietrich *et al.*, 2015; Souto *et al.*, 2019). The most plausible explanation for this association is the destruction of tooth-supporting tissues, modulated by an impaired ability to repair damaged tissue due to dysfunction of gingival fibroblasts, decreased microcirculatory function and immune system deficiency, overproduction of inflammatory molecules and suppression of anti-inflammatory molecules, thereby leading to an inflammatory destruction of connective tissue and alveolar bone (Hanioka *et al.*, 2011). Smoking is considered a grade modifier in the classification of periodontitis, as it affects periodontitis (greater severity and extent at earlier ages) and the response to treatment (Tonetti *et al.*, 2018). Systematic reviews have shown that the risk of incidence and progression of periodontitis can be reversed after smoking cessation (Leite *et al.*, 2018; Souto *et al.*, 2019). A cohort study demonstrated that smoking cessation was associated with a reduction in tooth loss, becoming similar to the risk of never smokers after approximately 10 to 20 years (Dietrich *et al.*, 2015).

Tooth loss was common, regardless of smoking status. Approximately one in ten individuals had no teeth, and one in five had a non-functional dentition. Data from the first Brazilian NHS (2013), showed that 11% of individuals aged 18 or older had lost all their teeth, and 23% had lost 13 or more (Nico *et al.*, 2016), thus the estimates for 2013 and 2019 are similar. The prevalence of current and former smokers was also high, despite the reduction since the implementation of the National Tobacco Control Program. With the implementation of tobacco control measures, including health education strategies and government regulation such as restrictions on advertising, marketing, and prohibition of the smoking in indoor locations, the prevalence of smoking among Brazilian men reduced from 43.3% in 1989 to 18.9% in 2013 and, among women, from 27.0% to 11.0% (INCA, 2024).

Since 2007, WHO (2013) has monitored the implementation of policies to reduce tobacco use and its potential risks, and in 2013 set the global target of a 30% reduction in smoking in the population aged 15 or over. There are six strategies: monitoring tobacco use and prevention policies; protecting people against smoking; offering help for tobacco addiction; warning about the dangers of tobacco use; prohibiting on advertising, promoting, and sponsoring the sale of tobacco; and increasing taxes and charges. All of these have been adopted by the Brazilian control program.

Individuals with higher income and schooling had fewer missing teeth. Income and education are attributes often used to characterize socioeconomic status, and their association with tooth loss in adults is consistent (Peres *et al.*, 2013; Seerig *et al.*, 2015; Laguzzi *et al.*, 2016; Ribeiro *et al.*, 2016). Socioeconomic position determines the hierarchy of power and access to resources of social groups and is, therefore, an important predictor of health and healthy behaviors (Niessen *et al.*, 2018). The social gradient in tooth loss persists in high-income, as well as in middle- and low-income countries, such as Brazil (Peres *et al.*, 2013; Niessen *et al.*, 2018). Behaviors, such as smoking, are related to adverse social circumstances. The effects of health determinants modulate the way that different groups, with different risks, vulnerabilities and capabilities, interact with each other and with their social and economic environment (Sheiham and Watt, 2000). Therefore, health-related behaviors and health status are more related to the social determinants of health than to individual choices.

Tooth loss increased with age. For every three years of life, there was an average loss of one tooth. This is due to the cumulative and irreversible nature of tooth loss (Kassebaum *et al.*, 2014). The association may denote a lifetime exposure to a curative and mutilating oral healthcare model, in which tooth extraction continues to be a common treatment choice to oral diseases (Russell *et al.*, 2013; Ribeiro *et al.*, 2016). Even in face of aesthetic, functional and psychosocial impacts, tooth loss is still mistakenly taken as a natural consequence of aging by many people, which can negatively influence prevention-related behaviors and decision-making (Ribeiro *et al.*, 2016).

Women experienced more tooth loss than men. There is a consistent body of evidence supporting the association between female sex and increased occurrence of tooth loss (Peres *et al.*, 2013; Ribeiro *et al.*, 2016; Nico *et al.*, 2016; Laguzzi *et al.*, 2016). It is usually attributed to women's higher utilization of dental health services, which may, in turn, increase the exposure to mutilating interventions and the risk of early tooth loss, considering the curative and disease-centered biomedical model of healthcare (Russell *et al.*, 2013), as observed in other studies in Brazil (Peres *et al.*, 2013; Ribeiro *et al.*, 2016).

Some limitations of this study should be considered. The self-reported record of tooth loss could introduce information bias, although studies demonstrate its validity when compared to clinical evaluation (Unell *et al.*, 1997). The questions used to assess tooth loss referred to the number of teeth lost. It can be challenging for participants to know or remember exactly how many teeth were lost, which may lead to underestimation for those with more missing teeth. The cross-sectional design limits causal inference between smoking and tooth loss. However, the coherence and consistency of our findings with the literature and the biological plausibility are consistent with a causal relationship.

Tooth loss is still common in the Brazilian population, as is the prevalence of smoking, despite its reduction, achieved with the implementation of control policies and actions. Noticeably, smoking is not only a risk factor for tooth loss. Worldwide, there is a high prevalence of chronic diseases and general health and oral health

problems related to smoking. The structural role of social determinants in health behaviors and health status completes the scenario. The high occurrence of these events, the emergence of new tobacco products and consumption patterns, as well as the complex causal relationship among them, highlights the urgent need to adopt measures for reducing tooth loss and increasing the efforts to control tobacco use, considering the role of social determinants of health. The consequences of tooth loss also require investment in oral rehabilitative care, aiming to reduce the damage and burden of disease. On the other hand, the need to reorient the oral healthcare model towards health promotion and the prevention of oral diseases becomes evident. Thus, it is imperative to recognize the common risk factors approach as an effective strategy in health promotion (Sheiham and Watt, 2000). This approach deals with behavioral risk factors (including smoking) shared by chronic conditions and encourages integrated strategies to reduce exposure to these factors, rather than traditional approaches focusing on specific diseases. It avoids duplicated efforts and pursues transdisciplinary health promotion actions to integrate oral and general health. Tobacco control policies are relatively low-cost and are among the best investments based on the principles of health promotion. Furthermore, it is important to address the structural determinants of health inequalities and recognize that focusing on approaches based solely on “lifestyle” ignores the social influences on health and isolates behaviors from their social context.

In conclusion, smoking was strongly associated with tooth loss in a population-based sample in Brazil, even considering the socioeconomic and demographic covariates. A gradient was observed between never, former and current smokers and tooth loss. Health services need to reorientate their efforts towards intersectoral approaches that can effectively address the common risk factors for improve general and oral health outcomes.

### Conflict of Interest Statement

The authors have no conflicts of interest to declare for this study.

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