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Tese

CÁRIE CORONÁRIA E CÁRIE RADICULAR EM ADULTOS E IDOSOS

Maurício dos Santos Moura

Porto Alegre (RS), dezembro de 2014.

MAURÍCIO DOS SANTOS MOURA

CÁRIE CORONÁRIA E CÁRIE RADICULAR EM ADULTOS E IDOSOS

Linha de pesquisa

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CORONAL AND ROOT CARIES IN ADULTS AND THE ELDERLY

Maurício dos Santos Moura

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Abstract

Coronal and root caries in adults and the elderly

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The aim of this thesis was to study adults and the elderly from South Brazil in regards to: (1) the prevalence, extent, and intra-oral distribution of coronal and root caries; (2) the relationship of educational status with coronal and root caries experience; (3) the prevalence estimates and risk indicators for coronal and root caries activity; and (4) the relationship of overweight and obesity with coronal and root caries experience. A cross-sectional population-based study was conducted between June 2011 and June 2012. A multistage sampling strategy was used to draw a representative sample of 1,023 individuals aged ≥35 years. Questionnaires recorded data on socio-demographic characteristics, oral hygiene habits, dental care, and smoking. Oral examination assessed gingival bleeding, gingival recession, and coronal and root caries. Anthropometric measures were collected to calculate the body mass index. Survey negative binomial models were used to assess the relationship of educational status, overweight and obesity with coronal and root caries experience. Survey Poisson regression models were used to assess the relationship of explanatory variables with coronal and root caries activity. The coronal and root caries prevalence was 99.73% (95% CI 99.31-100.00) and 41.14% (95% CI 37.57-44.72), respectively. The prevalence of coronal and root caries activity was 34.26% (95% CI 27.13-41.38) and 14.73% (95% CI 11.16-18.30), respectively. The mean coronal DMFT and root DFT scores was 18.73 (95% CI 18.29-19.17) and 1.15 (95% CI 0.95-1.34), respectively. The mean coronal DMFS and root DFS scores was 66.56 (95% CI 63.30-69.83) and 1.49 (95% CI 1.25-1.73), respectively. The mean coronal DMFS score was significantly higher in the older age groups compared to individuals aged 35-44 years. The mean coronal DS score significantly decreased between individuals aged 35-44 years and those aged 45-59 and ≥60 years. The mean coronal MS score significantly increased with age. The root caries estimates were significantly higher in individuals aged 45-59 and ≥60 years compared to those aged 35-44 years. Molars and premolars were the teeth most affected by coronal and root caries, respectively. The likelihood of coronal caries significantly decreased with a high educational status. The probability of root caries significantly increased with a high educational status. Overweight and obesity were not significantly associated with coronal and root caries experience. The likelihood of coronal caries activity significantly decreased with age ≥60 years, a higher tooth brushing frequency, a higher proximal tooth cleaning frequency, regular dental care, and a larger number of retained teeth, and significantly increased with ≥60% of bleeding sites. The likelihood of root caries activity significantly decreased with a larger number of retained teeth, and significantly increased with an intermediate-high educational status and a larger number of teeth with recession. Coronal caries activity significantly increased the probability of root caries activity by 394%. Thus, it was possible conclude that: (1) coronal and root caries were highly prevalent in this Brazilian population, and molars and premolars were the teeth most attacked by coronal and root caries, respectively; (2) educational status was a risk indicator for both coronal and root caries, but individuals with a high educational status should only be considered at high risk for root caries; (3) caries activity was highly prevalent in adults and the elderly, and those with coronal caries activity should be considered at high risk for root caries activity; and (4) overweight and obese individuals should not be considered at high risk for both coronal and root caries.

Key words: dental caries, root caries, DMF index, epidemiology, prevalence, risk factors, educational status, overweight, obesity, body mass index, adults

Abstract (in Portuguese)

Cárie coronária e cárie radicular em adultos e idosos

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O objetivo desta tese foi estudar a população adulta e idosa do sul do Brasil em relação: (1) à prevalência, extensão e distribuição intra-bucal de cárie coronária e cárie radicular; (2) à associação do nível educacional com a experiência de cárie coronária e cárie radicular; (3) às estimativas de prevalência e indicadores de risco para cárie coronária e cárie radicular; e (4) à associação do sobrepeso e obesidade com a experiência de cárie coronária e cárie radicular. Um estudo transversal de base-populacional foi conduzido entre junho de 2011 e junho de 2012. Uma estratégia de amostragem em múltiplos estágios foi usada para selecionar uma amostra representativa de 1.023 indivíduos com idade ≥35 anos. Questionários registraram dados sobre características sociodemográficas, hábitos de higiene oral, acesso a serviços odontológicos e tabagismo. Exames clínicos avaliaram sangramento gengival, recessão gengival, cárie coronária e cárie radicular. Medidas antropométricas foram coletadas para o cálculo do índice de massa corporal. Regressão binomial negativa foi utilizada para avaliar a associação do nível educacional, sobrepeso e obesidade com a experiência de cárie coronária e cárie radicular. Regressão de Poisson foi utilizada para avaliar a associação entre as variáveis explanatórias e a atividade de cárie coronária e cárie radicular. A prevalência de cárie coronária e cárie radicular foi de 99,73% (95% IC 99,31-100,00) e 41,14% (95% IC 37,57-44,72), respectivamente. A prevalência de atividade de cárie coronária e cárie radicular foi de 34,26% (95% IC 27,13-41,38) e 14,73% (95% IC 11,16-18,30), respectivamente. A média do CPOD coronário e COD radicular foi de 18,73 (95% IC 18,29-19,17) e 1,15 (95% IC 0,95-1,34), respectivamente. A média do CPOS coronário e COS radicular foi de 66,56 (95% IC 63,30-69,83) e 1,49 (95% IC 1,25-1,73), respectivamente. A média do CPOD coronário foi significativamente maior nos grupos mais velhos comparados aos indivíduos com idade entre 35-44 anos. A média do CS coronário diminuiu significativamente entre indivíduos com idade entre 35-44 anos e aqueles com idade entre 45-59 e ≥60 anos. A média do PS coronário aumentou significativamente com o aumento da idade. As estimativas para cárie radicular foram significativamente maiores em indivíduos com idade entre 45-59 e ≥60 anos comparados àqueles com idade entre 35-44 anos. Molares e pré-molares foram os dentes mais afetados por cárie coronária e cárie radicular, respectivamente. A probabilidade de cárie coronária diminuiu significativamente com um alto nível educacional. A probabilidade de cárie radicular aumentou significativamente com um alto nível educacional. Sobrepeso e obesidade não foram significativamente associados com a experiência de cárie coronária e cárie radicular. A probabilidade de atividade de cárie coronária aumentou significativamente com idade ≥60 anos, uma maior frequência de escovação dentária, uma maior limpeza dentária interproximal, visita regular ao dentista e um maior número de dentes retidos, e aumentou significativamente com ≥60% de sítios sangrantes. A probabilidade de atividade de cárie radicular diminuiu significativamente com um maior número de dentes retidos, e aumentou significativamente com um intermediário-alto nível educacional e um maior número de dentes com recessão. A atividade de cárie coronária aumentou significativamente a probabilidade de atividade de cárie radicular em 394%. Assim, foi possível concluir que: (1) a cárie coronária e cárie radicular foram altamente prevalentes nesta população brasileira, e molares e pré-molares foram os dentes mais acometidos por cárie coronária e cárie radicular, respectivamente; (2) o nível educacional foi um indicador de risco para ambas cárie coronária e cárie radicular, mas indivíduos com um alto nível educacional devem ser somente considerados em alto risco para cárie radicular; (3) a atividade de cárie foi altamente prevalente em adultos e idosos, e aqueles com atividade de cárie coronária devem ser considerados em alto risco para atividade de cárie radicular; (4) os indivíduos com sobrepeso e obesos não devem ser considerados em alto risco para ambas cárie coronária e cárie radicular.

Palavras-chave: cárie dentária, cárie radicular, índice CPO, epidemiologia, prevalência, fatores de risco, nível educacional, sobrepeso, obesidade, índice de massa corporal, adultos

Preface

This thesis is based on the following papers, which are attached at the end of this document.

I. Maurício S Moura, Juliana J Jardim, Fernando S Rios, Ricardo SA Costa, Alex N Haas, Wagner Marcenes, Marisa Maltz. Prevalence, extent, and intra-oral distribution of coronal and root caries among adults and the elderly from South Brazil: a population-based study.

II. Maurício S Moura, Juliana J Jardim, Fernando S Rios, Ricardo SA Costa, Alex N Haas, Wagner Marcenes, Marisa Maltz. Educational status as a risk indicator for coronal and root caries among adults and the elderly from South Brazil.

III. Maurício S Moura, Juliana J Jardim, Fernando S Rios, Ricardo SA Costa, Alex N Haas, Wagner Marcenes, Marisa Maltz. Coronal and root caries activity among adults and the elderly from South Brazil: prevalence estimates and assessment of risk indicators.

IV. Maurício S Moura, Juliana J Jardim, Fernando S Rios, Ricardo SA Costa, Alex N Haas, Marisa Maltz. Overweight and obesity are not associated with coronal and root caries experience in adults and the elderly.

Figures list

Abbreviations list

UNDP	-	United Nations Development Programme
DMF	-	decayed, missing, and filled
DMFT	-	decayed, missing, and filled teeth
DMFS	-	decayed, missing, and filled surfaces
DFT	-	decayed and filled teeth
DFS	-	decayed and filled surfaces
RCI	-	root caries index
95%CI	-	95% confidence interval
BMI	-	body mass index
IRR	-	incidence rate ratio
PR	-	prevalence ratio
SE	-	standard error

Introduction

In the past few decades, the developing and developed countries have undergone a demographic transition: the proportion of the population older than 60 years has increased substantially (1-4). Fertility rates as well as infant mortality rates decreased, and as a result, life expectancy at birth has improved (1-4). According to the United Nations Development Programme (UNDP), the life expectancy in Brazil has increased 17.9% between 1980 and 2013 (5). In parallel with demographic transition, epidemiological transition has altered morbidity-mortality profiles, where chronical and degenerative diseases are predominant (6). Oral diseases are extremely common chronic diseases and are important public health problems because of their prevalence, impact on individuals and society, and treatment expenses (7). Dental caries have historically been considered the most important global oral health burdens (7). Coronal caries in children and adolescents has been exhaustively explored in population-based studies, while data on adults and the elderly are less prevalent. Furthermore, at present, because people living longer (1-4), retaining their teeth for longer (8), and experiencing greater exposure of root surfaces (9), root caries is emerging as a pressing public health concern.

Epidemiological surveys typically report estimates of prevalence rates, defined as the proportion of a population found to have the disease, for coronal and root caries. While numerous indices for measuring dental caries have been suggested over the past decades, the decayed, missing, and filled (DMF) index remains the primary measure used to express the caries status of a population. This index reports the extent of caries on the tooth as a whole (DMFT) or on individual surfaces of the tooth (DMFS). When assessing root surfaces, the "missing" component is not considered (DFT and DFS indexes). Root caries are also commonly reported using the root caries index (RCI), which is based on the assumption that the root surface must be exposed to the oral environment in order to be at risk of developing root caries (10). The RCI estimates the number of decayed and filled surfaces/teeth based on the number of surfaces/teeth with gingival recession.

Globally, the prevalence of coronal caries is high among adults and elderly individuals, as the disease affects almost 100% of the population in a majority of the countries (11, 12). The coronal caries experience varies substantially in different parts of the world as well as within the same region or country (11-13). A number of public health measures including effective use of fluorides and improved access and use of dental services have resulted in a decline in the occurrence of coronal caries over the past few decades. In Brazil, a decrease in the rates of coronal caries in adults aged 35-44 years was observed between 2003 and 2010 (14, 15). However, the mean coronal DMFT score remains high in both the 35-44 and 65-74 year age groups.

Numerous cross-sectional studies have investigated the prevalence rates of root caries in adults and elderly individuals, with conflicting results (Table 1). The 2010 Brazilian nationwide survey showed that less than 20% of adults were affected by root caries and no more than 11% of the exposed root surfaces were decayed or filled (16). In contrast, higher rates were reported by studies conducted in Thailand (17), China (18), Greece (19), England (20), Germany (21), and Sri Lanka (22). Prospective cohort studies reported that older individuals exhibit higher rates of new root caries (23, 24). Thus, there is evidence to suggest that root caries is gradually becoming a public health concern among adults and elderly individuals.

It has been reported that maxillary and mandibular molars are the most common sites for occurrence of coronal caries in adults (25). The premolars and molars were most frequently affected by root caries in individuals aged 35-44 years and those older than 60 years (16, 18, 22).

The rates of dental caries have changed over time, with a decline in the proportion of coronal caries and an increase in the rates of root caries becoming apparent. Therefore, it is plausible to suggest the need for periodic studies exploring both diseases. Furthermore, there is a lack of population-based studies combining data on coronal and root caries, which may help to better understand oral health initiatives in older individuals.

Table 1. Cross-sectional population-based studies published from 2000 in regards to the root caries prevalence, mean root DFT score, and RCI among adults and the elderly.

Authors	Year		Adults			Elderly individuals		
		Country	Prevalence, %	DFT	RCI, %	Prevalence, %	DFT	RCI, %
Nicolau et al.	2000	Thailand	-	-	-	18.2	0.58	-
Lin et al.	2001	China	10.0	0.10	-	37.0	0.70	-
Steele et al.	2001	England	-	-	-	50.0	2.60	26.0
Splieth et al.	2004	Germany	34.8	1.23	7.10	53.6	1.18	10.4
Kularatne and Ekanayake	2007	Sri Lanka	-	-	-	89.7	3.80	25.0
Du et al.	2009	China	13.1	0.21	6.29	43.9	1.00	11.9
Mamai-Homata et al.	2012	Greece	11.1	0.39	2.53	38.3	2.66	9.7
Marques et al.	2013	Brazil	16.7	0.42	6.50	13.6	0.32	11.2

Even though overall rates of coronal caries continue to decline, there exists a disparity in the occurrence of dental caries among groups belonging to different socioeconomic strata. A recent systematic review showed an inverse relationship between socioeconomic indicators and coronal caries in adults aged 19-60 years (26). Therefore, strategies aimed at preventing coronal caries should be implemented in the lower socioeconomic groups. On the other hand, the relationship between socioeconomic indicators and root caries is poorly understood and cross-sectional studies have reported conflicting results (17-19). In the risk analyses, educational status has emerged as one of the most frequently used socioeconomic indicators for root caries as it is stable and is established in early adulthood. A study examining Chinese individuals aged 35-44 and 65-74 years showed no relationship between educational status and root caries (18). Mamai-Homata et al. (19) found similar results among an elderly Greek population aged 65-74 years, but not among Greek adults in the 35-44 age range. The latter group showed that adults with low educational status were more likely to have root caries. In contrast, Nicolau et al. (17) showed that Thai individuals older than 60 years of age and with high educational status were most likely to have root caries. Although these studies have used multivariate risk assessment models that were adjusted for a wide range of covariates, only one report took into account the potential role of clinical outcomes in the development of root caries (17). Furthermore, there is evidence to suggest that the number of retained teeth (8), number of exposed root surfaces (9) and coronal caries status (26) are all significantly associated with different social conditions. Therefore, it becomes apparent that the literature provides inconsistent results on the relationship between root caries and socioeconomic indicators. Moreover, there is a need to model data using comprehensible theoretical frameworks.

For decades dental caries have been defined by the presence or absence of cavitation (27). However, this type of diagnosis does not take into consideration the dynamic nature of caries and therefore does not reflect the presence of disease sufficiently. Current studies recommend that diagnostic categories make distinctions in the status of activity of the carious lesions and have also shown the feasibility of detecting lesion activity in a reliable and accurate manner (28-32). Caries activity is rarely evaluated in epidemiological surveys. Very few prevalence or incidence studies examine caries activity in children (33-35) and there are no population-based studies examining the same in adults and elderly individuals. Research in the field of coronal and root caries would help develop and understand health policies directed towards disease control.

It is believed that oral diseases have many risk factors that are common to a number of chronic disorders (36). A high sugar diet is recognized as a key factor in the caries process (37) and is also related to weight gain (38, 39). Obesity is defined as abnormal or excessive fat accumulation that represents a risk to the general health of an individual (40). Current evidence suggests that obesity has become a public health problem in developed as well as developing nations (41, 42). The current literature suggests that overweight or obese individuals are at an increased risk of dental caries as these conditions may share a common risk factor. However, a systematic review and meta-analysis exploring the relationship between obesity and dental caries in children showed inconclusive findings, after evaluating studies published between 1980 and 2010 (43). Other recent studies have also shown conflicting results (44-49). To date, this relationship has not been evaluated in the adult and elderly population.

Aims

The aim of this thesis was to study a representative sample of adults and the elderly from South Brazil in regards to:

* the prevalence, extent, and intra-oral distribution of coronal and root caries (Paper I);
* the relationship of educational status with coronal and root caries experience (Paper II);
* the prevalence estimates and risk indicators for coronal and root caries activity (Paper III);
* the relationship of overweight and obesity with coronal and root caries experience (Paper IV).

Aims (in Portuguese)

O objetivo desta tese foi estudar uma amostra representativa de adultos e idosos do sul do Brasil em relação:

* à prevalência, extensão e distribuição intra-oral de cárie coronária e cárie radicular (Artigo I);
* à associação do nível educacional com a experiência de cárie coronária e cárie radicular (Artigo II);
* às estimativas de prevalência e indicadores de risco para cárie coronária e cárie radicular (Artigo III);
* à associação do sobrepeso e obesidade com a experiência de cárie coronária e cárie radicular (Artigo IV).

Materials and methods

This cross-sectional study included 1,225 individuals aged ≥35 years from Porto Alegre, South Brazil. The fieldwork was conducted from June 2011 to June 2012. The study protocol was approved by the Federal University of Rio Grande do Sul Research Ethics Committee (19794/11). Signed informed consent was obtained from all study participants.

Sample size calculation

This was a multi-disciplinary study measuring a variety of oral outcomes; therefore, the sample size calculation used a 50% prevalence (worst-case scenario) for any oral condition assessed. A multistage sampling strategy was employed but was estimated to yield approximately 50% inefficiency. A standard formula for prevalence estimation was applied adjusting the sample size for this design effect. Assuming a ±4% precision level and a 95% confidence interval (CI), a sample size of 940 individuals was estimated. The minimum size of this sample to provide 80% statistical power and identify an odds ratio of 1.5 and/or a risk ratio of 1.2 was estimated to be 816 individuals (50). The calculation was based on the assumption that 50% of the unexposed population and 60% of the exposed population would have the outcome of interest, with an α equal to 0.05 and a β equal to 0.20.

Sampling strategy

This study used a multistage stratified random sampling strategy (Figure 1) based on information provided by governmental agencies (51). In the first stage, the city was divided into 86 neighbourhoods (primary sampling units [PSUs]). The PSUs were then divided into high- versus low-income strata. Low-income PSUs were those in which ≥35% of the heads of families had a monthly income of ≤5 standard Brazilian salaries (51). PSUs were randomly selected in proportion to the number of PSUs in each stratum. In the second stage, random sectors (map areas comprising approximately 300 households) were selected in proportion to the total number of sectors in each PSU; 48 of the 373 elegible sectors were selected, 34 and 14 from low- and high-income strata, respectively. In the third and final stage, consecutive households were selected (beginning at the sector starting point and continuing until the sector sample size was reached). The number of individuals to be selected within each sector was estimated based on the proportional distribution of the sample size according to the number of individuals aged ≥35 years who were living in each sector. All household members aged ≥35 years were eligible for the study. Individuals with mental or systemic health conditions that precluded the realization of interviews or clinical examinations were excluded. Non-residential establishments such as nursing homes and commercial establishments were not approached.

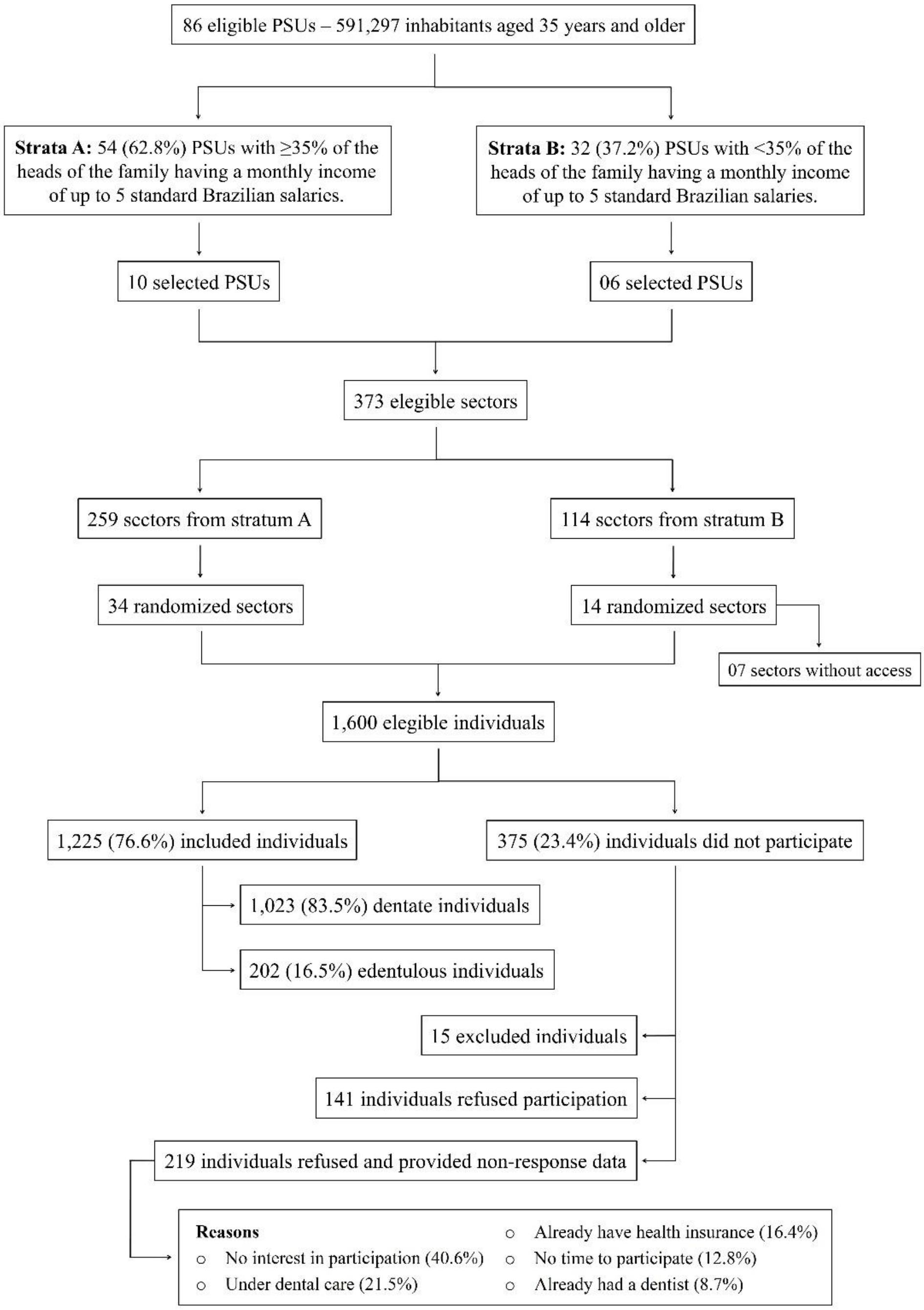

Figure 1. Flowchart of sampling strategy and response rate.

Data collection

Study participants were interviewed and underwent an oral examination in their own homes, performed by three trained and calibrated researchers (FSR, MSM and RSAC). A structured questionnaire comprising questions regarding socio-demographic characteristics, oral hygiene habits, dental care, and smoking was used. A test-retest approach was performed to assess the reliability of the questionnaire (unweighted Cohen's kappa varied from 0.91 to 0.99).

The clinical examination was conducted in the supine position. Field equipment included portable lights, an air compressor, plane mouth mirrors, and periodontal probes. Two examiners (FSR and RSAC) performed the gingival examination. Gingivitis was assessed using the gingival bleeding index (52). Gingival recession was defined as the distance from the cement-enamel junction to the free gingival margin. After teeth cleaning and drying, a single examiner (MSM) assessed coronal and root caries by determining whether the teeth surfaces were sound, decayed, missing, and filled. Coronal lesions were classified as follows: [1] active non-cavitated, opaque and dull-white surface with surface continuity; [2] inactive non-cavitated, shiny surface with different degrees of brownish discoloration and surface continuity; [3] active cavitated, localized surface destruction with opaque and dull-white enamel, and soft dentin; and [4] inactive cavitated, localized surface destruction with shiny enamel and hard dentin. Root lesions were graded as follows: [1] active non-cavitated, opaque and dull-yellow surface with surface continuity; [2] inactive non-cavitated, shiny surface with different degrees of yellowish discoloration and surface continuity; [3] active cavitated, localized surface destruction with opaque and dull-yellow cementum, and soft dentin; and [4] inactive cavitated, localized surface destruction with shiny cementum and hard dentin. Anthropometric data were collected for the calculation of body mass index (BMI, weight (kg)/height $(m)^2$). Weight was obtained using a 150 kg digital scale. Height was measured to the nearest full centimeter using an inelastic metric tape. The measurements were made by three researchers (MSM, FSR, and RSAC) with the participants wearing no shoes. Intra-examiner reliability for the caries assessment was conducted by repeated examinations in 5% of the sample within a 1-week interval. The lowest unweighted Cohen's kappa was 0.77. Similarly, intra-examiner reliability for the gingival assessment revealed weighted (±1 mm) Cohen's kappa values of 0.98 and 0.99, and an inter-examiner value of 0.91.

Non-response analysis

In statistical analyses, non-response was accounted for by using the inverse probability weighting strategy (53). A non-response weight variable considering eligible and actual participants as well as the distributions of age, sex, and educational status was generated for each sector.

A total of 375 (23.43%) individuals did not participate in the Survey. Reasons for non-participation are described in Figure 1. Some questions in the questionnaire were answered by 219 (58.40%) non-respondents; these data were compared with data from the individuals included in the final sample. The non-respondents were slightly older than the respondents (mean age 55.50 ± 11.80 *vs.* 52.60 ± 11.80 years, $P = 0.001$), and the percentage of individuals with a high educational status was significantly higher in the non-respondent group than in the respondent group. No significant differences regarding the proportion of men versus women and the self-reported mean number of missing teeth were found between the two groups.

Data analysis

The present data analysis included 1,023 dentate individuals. In the risk models that comprised weight status as an explanatory variable, underweight individuals or those in which anthropometric measures were not obtained were excluded ($n = 21$). Coronal caries was analyzed according to the [1] extent, defined as the number of decayed, missing, and filled surfaces (DMFS) or teeth (DMFT); [2] prevalence, defined as the percentage of individuals with at least one decayed, missing, or filled tooth (DMFT = 0 or DMFT ≥1); and [3] activity prevalence, define as the percentage of individuals with at least one active lesion. Root caries was analyzed according to the [1] extent, defined as the number of decayed and filled surfaces (DFS) or teeth (DFT); [2] prevalence, defined as the percentage of individuals with at least one decayed or filled tooth (DFT = 0 or DFT ≥1); [3] Root caries index (RCI), defined as the percentage of teeth with an exposed root surface (gingival recession of ≥1 mm) that is decayed or filled (10); and [4] activity prevalence, defined as the percentage of individuals with at least one active lesion. Prevalence estimates based on caries experience were defined considering two different criteria: [1] including non-cavitated and cavitated lesions and [2] excluding inactive non-cavitated lesions.

Participant age was categorized as 35-44, 45-59, or ≥60 years. Educational status was based on the number of years of education and was categorized as low (0-8 years), intermediate (9-11 years), or high (>11 years). Tooth brushing and proximal tooth cleaning frequency were dichotomized as ≤1 time/day versus ≥2 times/day and <1 time/day versus ≥1 time/day, respectively. Dental care in the last 3 years was dichotomized as irregular (no dental visit or visits only for emergencies) versus regular (visits for prevention with a frequency of ≥2 times/year). Former and current smokers were considered to have had exposure to cigarette smoking. The number of packs of cigarettes consumed in a lifetime (pack-years) was calculated by multiplying the number of cigarettes consumed per day by the years of habit, divided by 20. Individuals were classified as never-smokers (0 pack-years), moderate smokers (<20 pack-years), or heavy smokers (≥20 pack-years). Weight status (BMI) was categorized using cutoffs recommended by WHO as follows: normal (≥18.5 and <25.0 kg/m^2), overweight (≥25.0 and <30.0 kg/m^2), and obese (≥30 kg/m^2) (54). Gingivitis was categorized according to the percentage of bleeding sites on probing (≤20%, 21% to 59%, and ≥60%). The number of retained teeth and number of teeth with recession of ≥1 mm were modeled as continuous variables.

Data analysis was performed using the STATA software (Stata 11.1 for Windows, Stata Corporation, College Station, Texas, USA). A sampling weight variable was computed using census information provided by the Brazilian Institute of Geography and Statistics. Complex survey commands were applied to account for cluster correlations expected for the multistage sampling strategy used in this study. Pair-wise comparisons of crude estimates were performed using the Wald test. The significance level was set at 5%. Survey negative binomial models were used to assess the relationship of educational status, overweight and obesity with coronal and root caries experience. Survey Poisson regression models were used to assess the relationship of explanatory variables with coronal and root caries activity. Estimates were adjusted for socio-demographic and behavioral variables (adjusted model 1). Clinical variables were added to the analysis in the adjusted model 2. A preliminary analysis using univariate models was performed, and variables showing associations with a $P<0.25$ were added to the multivariate models. Maintenance of variables in the final model was determined by a combination of a $P<0.05$ and analyses of confounders and interactions (55). Incidence rate ratio (IRR), prevalence ratio (PR) and 95% CI were estimated and reported.

Results

A total of 1,600 individuals were eligible for the present study (Figure 1). Of them, 375 (23.43%) did not participate (non-respondents), resulting in a final sample of 1,225 (76.56%) individuals. A total of 1,023 (63.93%) dentate individuals were investigated, among which 398 (38.91%) were men and 625 (61.09%) were women aged 35-95 years (Table 2).

As shown in Table 3, the overall coronal caries prevalence was 99.73% (95% CI 99.31-100.00) and remained stable among the age groups. The mean coronal DMFT score was significantly higher in the older age groups compared to individuals aged 35-44 years.

As shown in Table 4, the overall root caries prevalence was 41.14% (95% CI 37.57-44.72). The root caries prevalence, mean root DFT score, and RCI were significanlty higher in individuals aged 45-59 and ≥60 years compared to those aged 35-44 years. The RCI was four-fold greater in individuals aged ≥60 years than in those aged 35-44 years.

Table 2. Study sample distribution according to age and sex.

Age, years	*n*	Males, %	Females, %
35-44	279	38.70	61.29
45-59	479	40.50	59.49
≥60	265	36.22	63.77
Total	1,023	38.91	61.09

Table 3. Mean coronal DMFT score and the percentage of individuals with coronal DMFT>0 according to age.

Age, years	DMFT, mean (95% CI)	DMFT>0, % (95% CI)
35-44	15.48 (14.59-16.36)[a]	99.59 (98.74-100.00)[a]
45-59	20.09 (19.54-20.63)[b]	99.70 (99.09-100.00)[a]
≥60	21.78 (20.79-22.77)[c]	100.00[a]
Total	18.73 (18.29-19.17)	99.73 (99.31-100.00)

95% CI = 95% confidence interval.
Different letters indicate a statistically significant difference between categories using the Wald test ($P \leq 0.05$).

Table 5 shows the mean coronal DMFS and root DFS scores according to age. The mean coronal DMFS and root DFS scores was 66.56 (95% CI 63.30-69.83) and 1.49 (95% CI 1.25-1.73), respectively. The mean coronal DS score significantly decreased between individuals aged 35-44 years and those aged ≥60 years. The mean coronal MS score significantly increased with age. The mean root DS and FS scores was significantly higher in individuals aged 45-59 and ≥60 years compared to those aged 35-44 years.

The pattern of intra-oral distribution of coronal caries was similar among the age groups (Figure 2). In all age groups, the molars were the most frequently teeth affected by coronal caries in both the maxillary and mandibular arches. As shown in Figure 3, the RCI was highest in the premolars of both the maxillary and mandibular arches in every age group.

Table 4. Mean root DFT score, the percentage of individuals with root DFT>0, and the Root Caries Index (RCI) according to age.

Age, years	DFT, mean (95% CI)	DFT>0, % (95% CI)	RCI, % (95% CI)
35-44	0.57 (0.35-0.79)[a]	24.37 (20.00-28.73)[a]	3.47 (2.15-4.79)[a]
45-59	1.40 (1.06-1.75)[b]	49.40 (41.76-57.05)[b]	11.62 (8.57-14.66)[b]
≥60	1.66 (1.26-2.06)[b]	54.86 (45.46-64.26)[b]	15.60 (10.74-20.47)[b]
Total	1.15 (0.95-1.34)	41.14 (37.57-44.72)	9.46 (7.67-11.26)

95% CI = 95% confidence interval.
Different letters indicate a statistically significant difference between categories using the Wald test ($P \leq 0.05$).

Table 5. Mean coronal DMFS and root DFS scores according to age.

	35-44 years old	45-59 years old	≥60 years old	Total
	CC, mean (95% CI)	CC, mean (95% CI)	CC, mean (95% CI)	CC, mean (95% CI)
DS				
Non-cavitated	0.54 (0.38-0.70)[a]	0.26 (0.05-0.47)[b]	0.05 (0.00-0.12)[b]	0.32 (0.20-0.44)
Dark shadowed*	0.54 (0.38-0.69)[a]	0.21 (0.12-0.29)[b]	0.15 (0.00-0.31)[b]	0.32 (0.22-0.42)
Cavitated	6.91 (5.83-8.00)[a]	6.74 (5.62-7.86)[a]	4.49 (3.70-5.27)[b]	6.28 (5.64-6.92)
MS	24.24 (20.27-28.21)[a]	49.38 (43.58-55.17)[b]	71.28 (63.86-78.70)[c]	44.93 (40.93-48.94)
FS	12.56 (9.94-15.18)[a]	18.00 (13.90-22.10)[b]	14.11 (11.49-16.72)[a]	15.02 (12.43-17.60)
DMFS	44.27 (40.75-47.79)[a]	74.39 (69.94-78.85)[b]	89.95 (82.62-97.27)[c]	66.56 (63.30-69.83)
	RC, mean (95% CI)	RC, mean (95% CI)	RC, mean (95% CI)	RC, mean (95% CI)
DS				
Non-cavitated	0	0	0	0
Cavitated	0.58 (0.38-0.77)[a]	1.06 (0.75-1.36)[b]	1.21 (0.71-1.71)[b]	0.91 (0.69-1.13)
FS	0.11 (0.04-0.18)[a]	0.80 (0.32-1.28)[b]	0.97 (0.63-1.30)[b]	0.58 (0.32-0.83)
DFS	0.69 (0.45-0.93)[a]	1.86 (1.42-2.30)[b]	2.18 (1.63-2.73)[b]	1.49 (1.25-1.73)

CC = coronal caries; RC = root caries.
*Surfaces with or without enamel breakdown.
Different letters indicate a statistically significant difference between categories of age using the Wald test ($P \leq 0.05$).

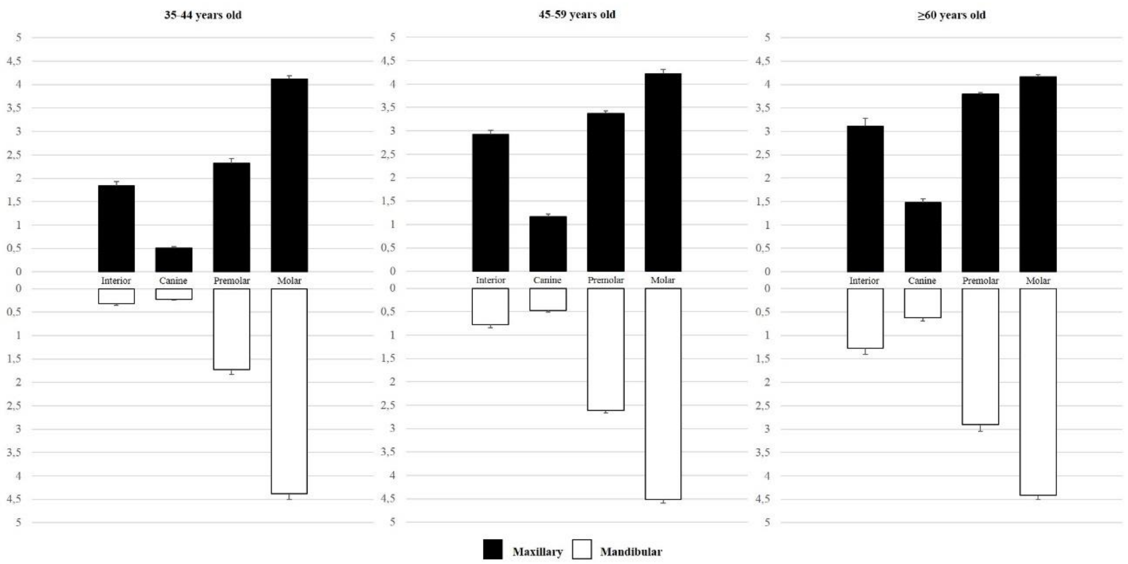

Figure 2. Mean coronal DMFT score according to tooth type and age.

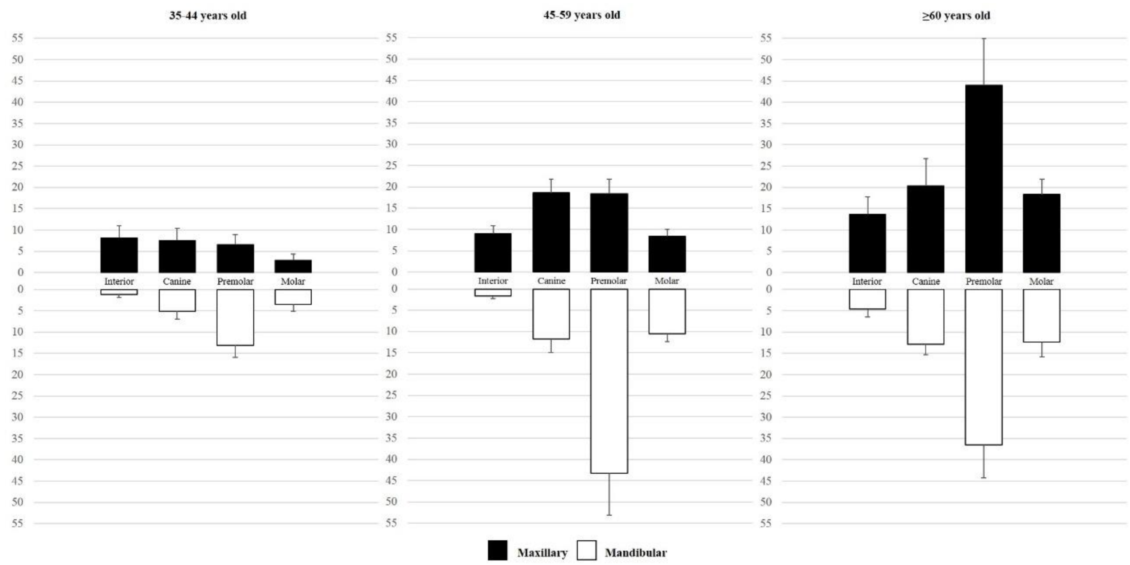

Figure 3. Root Caries Index (%) according to tooth type and age.

As shown in Table 6, coronal DMFT scores significantly differed according to sex, age, educational status, proximal tooth cleaning frequency, dental care frequency, and exposure to cigarette smoking. Root DFT scores significantly differed according to sex, age, tooth brushing frequency, dental care frequency, and exposure to cigarette smoking.

Table 6. Study sample distribution and coronal and root caries experience according to socio-demographic and behavioral characteristics.

	n (%)	Coronal caries		Root caries	
		DMFT (95% CI)	*P*[a]	DFT (95% CI)	*P*[a]
Sex					
Male	398 (38.91)	17.86 (17.34-18.38)	ref.	1.37 (1.10-1.64)	ref.
Female	625 (61.09)	19.46 (18.74-20.18)	0.002	0.95 (0.75-1.16)	0.005
Age, years					
35-44	279 (27.27)	15.48 (14.59-16.36)	ref.	0.57 (0.35-0.79)	ref.
45-59	479 (46.82)	20.09 (19.54-20.63)	<0.001	1.40 (1.06-1.75)	0.001
≥60	265 (25.90)	21.78 (20.79-22.77)	<0.001	1.66 (1.26-2.06)	<0.001
Educational status					
Low	583 (56.99)	19.38 (18.69-20.07)	ref.	1.09 (0.91-1.27)	ref.
Intermediate	328 (32.06)	18.60 (17.83-19.37)	0.11	1.09 (0.90-1.28)	0.97
High	112 (10.95)	16.68 (15.30-18.05)	0.006	1.46 (0.43-2.50)	0.43
Tooth brushing frequency					
≤1 time/day	118 (11.53)	20.32 (18.73-21.92)	ref.	1.91 (1.20-2.62)	ref.
≥2 times/day	905 (88.47)	18.49 (17.91-19.08)	0.06	1.03 (0.88-1.19)	0.01
Proximal tooth cleaning frequency					
<1 time/day	533 (52.10)	19.36 (19.01-19.71)	ref.	1.22 (1.06-1.38)	ref.
≥1 time/day	490 (47.90)	18.02 (17.28-18.76)	0.001	1.07 (0.79-1.35)	0.17
Dental care frequency					
None or irregular	788 (77.03)	19.22 (18.60-19.83)	ref.	1.27 (0.98-1.57)	ref.
Regular	235 (22.97)	17.21 (15.57-18.85)	0.05	0.75 (0.55-0.95)	0.02
Exposure to cigarette smoking					
Never-smoker	463 (45.26)	18.63 (17.89-19.36)	ref.	0.80 (0.62-0.99)	ref.
Moderate smoker	299 (29.23)	17.85 (16.63-19.08)	0.31	1.21 (0.81-1.61)	0.01
Heavy smoker	261 (25.51)	20.20 (19.41-20.99)	0.005	1.77 (1.33-2.20)	0.002
Total	1,023 (100.00)	18.73 (18.29-19.17)		1.15 (0.95-1.34)	

95% CI, 95% confidence interval.
[a]Wald test.

In the multivariate model, coronal caries experience was associated with sex, age, educational status, and proximal tooth cleaning (Table 7). An increased likelihood of coronal caries was observed for individuals aged 45-59 years (IRR 1.29, 95% CI 1.19-1.40) and ≥60 years (IRR 1.39, 95% CI 1.29-1.49) and among women (IRR 1.09, 95% CI 1.04-1.14). A higher proximal tooth cleaning frequency was significantly associated with a lower probability of coronal caries (IRR 0.94, 95% CI 0.91-0.97). The likelihood of coronal caries was lower for participants with a high educational status than for those with a low educational status (IRR 0.88, 95% CI 0.78-0.99).

Table 7. Association between coronal caries experience and explanatory variables (unadjusted and adjusted negative binomial regression analysis).

	Unadjusted model		Adjusted model[a]	
	IRR (95% CI)	*P*	IRR (95% CI)	*P*
Sex				
Male	1.00		1.00	
Female	1.08 (1.03-1.14)	0.002	1.09 (1.04-1.14)	0.001
Age, years[b]				
35-44	1.00		1.00	
45-59	1.29 (1.20-1.39)	<0.001	1.29 (1.19-1.40)	<0.001
≥60	1.40 (1.31-1.50)	<0.001	1.39 (1.29-1.49)	<0.001
Educational status[b]				
Low	1.00		1.00	
Intermediate	0.95 (0.91-1.01)	0.11	1.00 (0.95-1.05)	0.92
High	0.86 (0.77-0.95)	0.008	0.88 (0.78-0.99)	0.04
Tooth brushing frequency				
≤1 time/day	1.00			
≥2 times/day	0.91 (0.82-1.00)	0.05		
Proximal tooth cleaning frequency				
<1 time/day	1.00		1.00	
≥1 time/day	0.93 (0.89-0.96)	0.002	0.94 (0.91-0.97)	0.003
Dental care frequency				
None or irregular	1.00			
Regular	0.89 (0.79-1.00)	0.05		
Exposure to cigarette smoking				
Never-smoker	1.00			
Moderate smoker	0.95 (0.87-1.04)	0.32		
Heavy smoker	1.08 (1.02-1.14)	0.005		
Gingivitis				
≤20	1.00			
>20 to <60	1.00 (0.94-1.05)	0.93		
≥60	1.10 (1.03-1.17)	0.005		

IRR, incidence rate ratio; 95% CI, 95% confidence interval.
[a]No difference between adjusted model 1 (socio-demographic and behavioral variables) and adjusted model 2 (socio-demographic and behavioral variables, and gingivitis) was found.
[b]Variables maintained in the final model independently of the *P*-value.

Table 8 shows the assocation between the mean root DFT score and explanatory variables. Individuals aged 45-59 years (IRR 2.21, 95% CI 1.45-3.38) or ≥60 years (IRR 2.81, 95% CI 2.13-3.70), and those with a lower tooth brushing frequency (IRR 0.68, 95% CI 0.48-0.95), irregular dental care (IRR 0.65, 95% CI 0.42-0.99), and moderate (IRR 1.38, 95% CI 1.04-1.83) or high (IRR 2.09, 95% CI 1.43-3.04) exposure to cigarette smoking were significantly associated with increased root DFT scores in the adjusted model 1. Individuals with intermediate (IRR 1.31, 95% CI 1.00-1.75) or high (IRR 1.57, 95% CI 1.06-2.31) educational status were more likely to have root caries. After adding gingivitis, the number of retained teeth, number of teeth with recession, and coronal DMFT scores to the analysis, the risk estimates changed accordingly (adjusted model 2). The likelihood of root caries was statistically significantly higher for higher coronal DMFT scores (IRR 1.11, 95% CI 1.07-1.14) and a larger number of teeth with recession (IRR 1.18, 95% CI 1.15-1.22). The probability of root caries decreased with a higher tooth brushing frequency (IRR 0.75, 95% CI 0.59-0.96) and a larger number of retained teeth (IRR 0.92, 95% CI 0.89-0.95). A high educational status increased the likelihood of root caries by 74% (IRR 1.74, 95% CI 1.11-2.72).

In regards to coronal and root caries activity, the mean number of coronal surfaces with non-cavitated and cavitated active lesion was 1.72 (standard error [SE] 0.19) and 0.75 (SE 0.18) in the age groups of 35-59 and ≥60 years, respectively ($P = 0.001$, Wald test). The mean number of root surfaces with cavitated active lesion was 0.29 (SE 1.09) in the younger group and 0.46 (SE 0.12) in the older group ($P = 0.21$, Wald test).

As shown in Table 9, the prevalence of coronal and root caries activity was 34.26% (95% CI 27.13-41.38) and 14.73% (95% CI 11.16-18.30), respectively. Significant differences in the coronal caries activity were observed according to age, educational status, tooth brushing frequency, proximal tooth cleaning frequency, and dental care frequency. Root caries activity significantly differed according to educational status, tooth brushing frequency, proximal tooth cleaning frequency, dental care frequency, and exposure to cigarette smoking.

As shown in Table 10, age ≥60 years (PR 0.54, 95% CI 0.37-0.80), a higher tooth brushing frequency (PR 0.56, 95% CI 0.43-0.74), a higher proximal tooth cleaning frequency (PR 0.78, 95% CI 0.65-0.93), and regular dental care (PR 0.32, 95% CI 0.22-0.46) were significantly associated with a lower prevalence of coronal caries activity in the first multivariate model. After adding gingivitis and the number of retained teeth to the analysis, the risk estimates increased slightly in all of these variables, except age (adjusted model 2). The probability of coronal caries activity decreased with age ≥60 years (PR 0.48, 95% CI 0.32-0.72), a higher tooth brushing frequency (PR 0.57, 95% CI 0.43-0.76), a higher proximal tooth cleaning frequency (PR 0.83, 95% CI 0.71-0.98), regular dental care (PR 0.35, 95% CI 0.25-0.50), and a larger number of retained teeth (PR 0.98, 95% CI 0.97-0.99), and increased with ≥60% of bleeding sites (PR 1.71, 95% CI 1.19-2.43).

Table 8. Association between root caries experience and explanatory variables (unadjusted and adjusted negative binomial regression analysis).

	Unadjusted model		Adjusted model 1[a]		Adjusted model 2[b]	
	IRR (95% CI)	*P*	IRR (95% CI)	*P*	IRR (95% CI)	*P*
Sex						
Male	1.00					
Female	0.69 (0.55-0.87)	0.005				
Age, years[c]						
35-44	1.00		1.00		1.00	
45-59	2.45 (1.48--4.07)	0.002	2.21 (1.45-3.38)	0.001	1.04 (0.70-1.53)	0.81
≥60	2.90 (1.95-4.32)	<0.001	2.81 (2.13-3.70)	<0.001	1.10 (0.73-1.65)	0.60
Educational status[c]						
Low	1.00		1.00		1.00	
Intermediate	0.99 (0.78-1.26)	0.97	1.31 (1.00-1.75)	0.04	1.10 (0.88-1.37)	0.35
High	1.33 (0.68-2.62)	0.36	1.57 (1.06-2.31)	0.02	1.74 (1.11-2.72)	0.01
Tooth brushing frequency						
≤1 time/day	1.00		1.00		1.00	
≥2 times/day	0.54 (0.38-0.76)	0.002	0.68 (0.48-0.95)	0.02	0.75 (0.59-0.96)	0.02
Proximal tooth cleaning frequency						
<1 time/day	1.00					
≥1 time/day	0.87 (0.71-1.08)	0.20				
Dental care frequency						
None or irregular	1.00		1.00			
Regular	0.59 (0.38-0.90)	0.02	0.65 (0.42-0.99)	0.04		
Exposure to cigarette smoking						
Never-smoker	1.00		1.00			
Moderate smoker	1.50 (1.16-1.93)	0.004	1.38 (1.04-1.83)	0.02		
Heavy smoker	2.18 (1.47-3.25)	0.001	2.09 (1.43-3.04)	0.001		
Gingivitis						
≤20	1.00					
>20 to <60	0.95 (0.62-1.46)	0.83				
≥60	0.92 (0.54-1.56)	0.75				
Coronal DMFT scores	1.09 (1.07-1.12)	<0.001			1.11 (1.07-1.14)	<0.001
No. of retained teeth	0.96 (0.94-0.97)	<0.001			0.92 (0.89-0.95)	<0.001
No. of teeth with recession	1.06 (1.04-1.08)	<0.001			1.18 (1.15-1.22)	<0.001

IRR, incidence rate ratio; 95% CI, 95% confidence interval.
[a]Estimates adjusted for socio-demographic and behavioral variables.
[b]Estimates adjusted for socio-demographic, behavioral, and clinical variables.
[c]Variables maintained in the final model independently of the *P*-value.

In the first multivariable model (Table 11), root caries activity was significantly associated with a higher proximal tooth cleaning frequency (PR 0.56, 95% CI 0.36-0.86), regular dental care (PR 0.40, 95% CI 0.18-0.90), and greater exposure to cigarette smoking (PR 2.18, 95% CI 1.27-3.74). After adding gingivitis, coronal caries activity, the number of retained teeth, and the number of teeth with recession to the analysis, the risk estimates changed accordingly (adjusted model 2). Proximal tooth cleaning frequency, dental care, and exposure to cigarette smoking were no longer associated with root caries activity. In addition, the probability of root caries activity decreased with a larger number of retained teeth (PR 0.88, 95% CI 0.86-0.90), and increased with intermediate-high educational status (PR 1.32, 95%CI 1.01-1.71) and a larger number of teeth with recession (PR 1.08, 95% CI 1.05-1.12). Coronal caries activity increased the likelihood of root caries activity by 394% (PR 4.94, 95% CI 3.23-7.55).

Table 9. Study sample distribution and coronal and root caries activity according to socio demographic and behavioral characteristics.

		Coronal caries activity		Root caries activity	
	n (%)	Prevalence (95% CI)	*P**	Prevalence (95% CI)	*P**
Sex					
Male	398 (38.91)	36.70 (24.50-48.89)	ref.	17.57 (9.61-25.54)	ref.
Female	625 (61.09)	32.18 (25.89-38.48)	0.46	12.31 (9.01-15.62)	0.25
Age, years					
35-59	758 (74.10)	37.99 (29.38-46.61)	ref.	14.66 (9.94-19.38)	ref.
≥60	265 (25.90)	22.05 (14.12-29.98)	0.01	14.96 (7.19-22.74)	0.94
Educational status					
Low	661 (64.61)	39.53 (30.49-48.57)	ref.	16.48 (11.99-20.97)	ref.
Intermediate-high	362 (35.39)	26.09 (19.42-32.77)	0.01	12.02 (8.16-15.88)	0.04
Tooth brushing frequency					
≤1 time/day	118 (11.53)	63.92 (42.55-85.29)	ref.	33.90 (9.75-58.06)	ref.
≥2 times/day	905 (88.47)	29.93 (22.76-37.09)	0.005	11.93 (9.10-14.76)	0.08
Proximal tooth cleaning frequency					
<1 time/day	533 (52.10)	41.26 (33.79-48.74)	ref.	19.17 (13.03-25.31)	ref.
≥1 time/day	490 (47.90)	26.44 (18.82-34.07)	<0.001	9.78 (6.88-12.67)	0.01
Dental care frequency					
None or irregular	788 (77.03)	41.58 (33.43-49.73)	ref.	17.56 (12.40-22.73)	ref.
Regular	235 (22.97)	11.57 (6.31-16.84)	<0.001	5.95 (1.80-10.11)	0.007
Exposure to cigarette smoking					
Never-smoker	463 (45.26)	31.00 (21.40-40.60)	ref.	10.82 (5.39-16.26)	ref.
Moderate smoker	299 (29.23)	34.89 (25.95-43.82)	0.42	13.57 (9.06-18.08)	0.26
Heavy smoker	261 (25.51)	40.12 (31.12-49.12)	0.10	24.54 (20.15-28.93)	0.003
Total	1,023 (100.00)	34.26 (27.13-41.38)		14.73 (11.16-18.30)	

95% CI, 95% confidence interval.
*Wald test.

Table 12 shows the weight status according to age. The overall prevalence of excessive body weight was 71.13% (95% CI 66.39-75.87), of which 39.80% (95% CI 35.18-44.41) were overweight and 31.33% (95% CI 26.50-36.16) were obese individuals.

Table 10. Association between coronal caries activity and explanatory variables (unadjusted and adjusted Poisson regression analysis).

	Unadjusted model		Adjusted model 1[b]		Adjusted model 2[c]	
	PR (95% CI)	*P*	PR (95% CI)	*P*	PR (95% CI)	*P*
Sex						
Male	1.00					
Female	0.87 (0.61-1.24)	0.43				
Age, years[a]						
35-59	1.00		1.00		1.00	
≥60	0.58 (0.37-0.88)	0.01	0.54 (0.37-0.80)	0.006	0.48 (0.32-0.72)	0.002
Educational status						
Low	1.00					
Intermediate-high	0.66 (0.49-0.87)	0.008				
Tooth brushing frequency						
≤1 time/day	1.00		1.00		1.00	
≥2 times/day	0.46 (0.31-0.69)	0.001	0.56 (0.43-0.74)	0.001	0.57 (0.43-0.76)	0.001
Proximal tooth cleaning frequency						
<1 time/day	1.00		1.00		1.00	
≥1 time/day	0.64 (0.52-0.78)	<0.001	0.78 (0.65-0.93)	0.01	0.83 (0.71-0.98)	0.03
Dental care frequency						
None or irregular	1.00		1.00		1.00	
Regular	0.27 (0.18-0.42)	<0.001	0.32 (0.22-0.46)	<0.001	0.35 (0.25-0.50)	<0.001
Exposure to cigarette smoking						
Never-smoker	1.00					
Moderate smoker	1.12 (0.82-1.53)	0.42				
Heavy smoker	1.29 (0.93-1.79)	0.11				
Gingivitis (bleeding sites), %						
≤20	1.00				1.00	
>20 to <60	1.35 (1.02-1.80)	0.03			1.25 (0.97-1.61)	0.07
≥60	2.15 (1.46-3.17)	0.001			1.71 (1.19-2.43)	0.006
No. of retained teeth	0.98 (0.96-0.99)	0.01			0.98 (0.97-0.99)	0.04

PR, prevalence ratio; 95% CI, 95% confidence interval.
[a]Variable maintained in the final model independently of the *P*-value;
[b]Estimates adjusted for socio-demographic and behavioral variables.
[c]Estimates adjusted for socio-demographic, behavioral, and clinical variables.

Table 13 shows coronal and root caries experience by socio-demographic and behavioral characteristics, and weight status. The total mean coronal DMFT and root DFT scores was 18.68 (95% CI 18.24-19.13) and 1.14 (95% CI 0.95-1.34), respectively. Coronal DMFT scores did not significantly differ according to tooth brushing frequency and dental care frequency, whereas root DFT scores did not significantly differ according to educational status and proximal tooth cleaning frequency. No significant differences in coronal and root caries experience were found among the weight status groups.

In the univariate and multivariate models, coronal caries experience was not significantly associated with overweight and obesity (Table 14). In the adjusted analysis, women (IRR 1.09, 95% CI 1.05-1.14), age groups of 45-59 years (IRR 1.31, 95% CI 1.20-1.42) and ≥60 years (IRR 1.40, 95% CI 1.30-1.50), and a proximal tooth cleaning frequency of ≥1 time/day (IRR 0.94, 95% CI 0.91-0.98) emerged as risk indicators for coronal caries experience.

Table 11. Association between root caries activity and explanatory variables (unadjusted and adjusted Poisson regression analysis).

	Unadjusted model		Adjusted model 1[b]		Adjusted model 2[c]	
	PR (95% CI)	*P*	PR (95% CI)	*P*	PR (95% CI)	*P*
Sex						
Male	1.00					
Female	0.70 (0.38-1.26)	0.21				
Age, years[a]						
35-59	1.00		1.00		1.00	
≥60	1.02 (0.51-2.02)	0.94	0.94 (0.47-1.84)	0.84	0.76 (0.51-1.15)	0.18
Educational status						
Low	1.00				1.00	
Intermediate-high	0.72 (0.53-1.00)	0.05			1.32 (1.01-1.71)	0.03
Tooth brushing frequency						
≤1 time/day	1.00					
≥2 times/day	0.35 (0.15-0.79)	0.01				
Proximal tooth cleaning frequency						
<1 time/day	1.00		1.00			
≥1 time/day	0.51 (0.32-0.80)	0.008	0.56 (0.36-0.86)	0.01		
Dental care frequency						
None or irregular	1.00		1.00			
Regular	0.33 (0.14-0.80)	0.01	0.40 (0.18-0.90)	0.03		
Exposure to cigarette smoking						
Never-smoker	1.00					
Moderate smoker	1.25 (0.80-1.95)	0.29	1.25 (0.82-1.92)	0.26		
Heavy smoker	2.26 (1.25-4.08)	0.01	2.18 (1.27-3.74)	0.008		
Gingivitis (bleeding sites), %						
≤20	1.00					
>20 to <60	1.06 (0.55-2.02)	0.83				
≥60	2.47 (1.18-5.15)	0.02				
Coronal caries activity						
Absent	1.00				1.00	
Present	5.78 (3.22-10.35)	<0.001			4.94 (3.23-7.55)	<0.001
No. of retained teeth	0.93 (0.91-0.94)	<0.001			0.88 (0.86-0.90)	<0.001
No. of teeth with recession	0.98 (0.95-1.00)	0.11			1.08 (1.05-1.12)	<0.001

PR, prevalence ratio; 95% CI, 95% confidence interval.
[a]Variable maintained in the final model independently of the *P*-value;
[b]Adjusted model 1 = estimates adjusted for sociodemographic and behavioral variables.
[c]Adjusted model 2 = estimates adjusted for sociodemographic, behavioral, and clinical variables.

Table 12. Excessive body weight according to age.

	Age, years			
	35-44, % (95% CI)	45-59, % (95% CI)	≥60, % (95% CI)	Total, % (95% CI)
Overweight	39.36 (29.16-49.56)[a]	38.30 (31.99-44.40)[a]	43.12 (36.08-50.15)[a]	39.80 (35.18-44.41)
Obese	33.18 (25.32-41.04)[a]	31.93 (28.97-34.90)[a]	27.36 (15.85-38.87)[a]	31.33 (26.50-36.16)
Total	72.55 (63.68-81.41)[a]	70.14 (65.45-74.83)[a]	70.48 (59.12-81.84)[a]	71.13 (66.39-75.87)

95% CI, 95% confidence interval.
Different letters indicate a statistically significant difference between categories using the Wald test ($P \leq 0.05$).

Table 13. Study sample distribution and coronal and root caries experience according to socio-demographic and behavioral characteristics, and weight status.

	n (%)	Coronal caries		Root caries	
		DMFT (95% CI)	P^a	DFT (95% CI)	P^a
Sex					
Male	394 (39.32)	17.79 (17.33-18.26)	ref.	1.37 (1.10-1.64)	ref.
Female	608 (60.68)	19.45 (18.72-20.18)	0.001	0.95 (0.74-1.16)	0.004
Age, years					
35-44	271 (27.05)	15.31 (14.41-16.22)	ref.	0.55 (0.33-0.76)	ref.
45-59	471 (47.01)	20.12 (19.59-20.65)	<0.001	1.42 (1.07-1.76)	0.001
≥60	260 (25.95)	21.76 (20.76-22.77)	<0.001	1.66 (1.26-2.07)	<0.001
Educational status					
Low	570 (56.89)	19.33 (18.63-20.04)	ref.	1.08 (0.90-1.26)	ref.
Intermediate	323 (32.24)	18.52 (17.78-19.26)	0.09	1.10 (0.91-1.29)	0.88
High	109 (10.88)	16.71 (15.14-18.27)	0.01	1.48 (0.42-2.54)	0.41
Tooth brushing frequency					
≤1 time/day	114 (11.38)	20.27 (18.65-21.90)	ref.	1.91 (1.18-2.64)	ref.
≥2 times/day	888 (88.62)	18.45 (17.86-19.05)	0.06	1.03 (0.88-1.19)	0.01
Proximal tooth cleaning frequency					
<1 time/day	518 (51.70)	19.27 (18.91-19.63)	ref.	1.21 (1.05-1.37)	ref.
≥1 time/day	484 (48.30)	18.03 (17.26-18.80)	0.004	1.07 (0.80-1.35)	0.20
Dental care frequency					
None or irregular	773 (77.15)	19.16 (18.52-19.80)	ref.	1.27 (0.97-1.56)	ref.
Regular	229 (22.85)	17.19 (15.46-18.92)	0.06	0.76 (0.55-0.97)	0.02
Exposure to cigarette smoking					
Never-smoker	454 (45.31)	18.62 (17.91-19.32)	ref.	0.81 (0.62-1.00)	ref.
Moderate smoker	293 (29.24)	17.81 (16.56-19.06)	0.29	1.22 (0.82-1.62)	0.01
Heavy smoker	255 (25.45)	20.09 (19.29-20.90)	0.006	1.73 (1.30-2.16)	0.002
Weight status					
Normal	272 (27.15)	18.48 (18.23-19.45)	ref.	1.33 (1.07-1.59)	ref.
Overweight	412 (41.12)	18.63 (17.69-19.57)	0.68	1.16 (0.88-1.44)	0.35
Obese	318 (31.74)	18.60 (17.80-19.41)	0.63	0.96 (0.65-1.27)	0.08
Total	1,002 (100.00)	18.68 (18.24-19.13)		1.14 (0.95-1.34)	

95% CI, 95% confidence interval.
[a]Wald test.

As shown in Table 15, root caries experience was not significantly associated with overweight and obesity in both univariate and multivariate models. In the adjusted model, a high educational status (IRR 1.76, 95% CI 1.02-3.07), higher coronal DMFT scores (IRR 1.11, 95% CI 1.07-1.15), a lower number of retained teeth (IRR 0.92, 95% CI 0.89-0.95), and a higher number of teeth with recession (IRR 1.15, 95% CI 1.15-1.22) were significantly associated with increased root DFT scores.

Table 14. Association between coronal caries experience and explanatory variables (unadjusted and adjusted negative binomial regression analysis).

	Unadjusted model		Adjusted model	
	IRR (95% CI)	*P*	IRR (95% CI)	*P*
Sex				
Male	1.00		1.00	
Female	1.09 (1.04-1.14)	0.001	1.09 (1.05-1.14)	<0.001
Age, years[a]				
35-44	1.00		1.00	
45-59	1.31 (1.21-1.41)	<0.001	1.31 (1.20-1.42)	<0.001
≥60	1.42 (1.32-1.52)	<0.001	1.40 (1.30-1.50)	<0.001
Educational status[a]				
Low	1.00		1.00	
Intermediate	0.95 (0.90-1.00)	0.09	0.99 (0.94-1.05)	0.96
High	0.86 (0.77-0.96)	0.01	0.89 (0.78-1.01)	0.08
Tooth brushing frequency				
≤1 time/day	1.00			
≥2 times/day	0.91 (0.82-1.00)	0.06		
Proximal tooth cleaning frequency				
<1 time/day	1.00		1.00	
≥1 time/day	0.93 (0.89-0.97)	0.006	0.94 (0.91-0.98)	0.01
Dental care frequency				
None or irregular	1.00			
Regular	0.89 (0.79-1.01)	0.07		
Exposure to cigarette smoking				
Never-smoker	1.00			
Moderate smoker	0.95 (0.87-1.04)	0.30		
Heavy smoker	1.07 (1.02-1.13)	0.006		
Weight status[a]				
Normal	1.00		1.00	
Overweight	0.98 (0.93-1.05)	0.68	0.98 (0.94-1.03)	0.62
Obese	0.98 (0.93-1.04)	0.63	0.98 (0.92-1.04)	0.55
Gingivitis				
≤20%	1.00			
21% to 59%	0.99 (0.93-1.05)	0.86		
≥60%	1.09 (1.02-1.17)	0.008		

IRR, incidence rate ratio; 95% CI, 95% confidence interval.
[a]Variables maintained in the final model independently of the *P*-value.

Table 15. Association between root caries experience and explanatory variables (unadjusted and adjusted negative binomial regression analysis).

	Unadjusted model		Adjusted model	
	IRR (95% CI)	*P*	IRR (95% CI)	*P*
Sex				
Male	1.00			
Female	0.69 (0.55-0.87)	0.005		
Age, years[a]				
35-44	1.00		1.00	
45-59	2.56 (1.53-4.29)	0.002	1.06 (0.71-1.60)	0.73
≥60	3.01 (2.00-4.53)	<0.001	1.12 (0.75-1.67)	0.52
Educational status[a]				
Low	1.00		1.00	
Intermediate	1.01 (0.79-1.30)	0.88	1.08 (0.88-1.34)	0.39
High	1.36 (0.69-2.70)	0.33	1.76 (1.02-3.07)	0.04
Tooth brushing frequency				
≤1 time/day	1.00			
≥2 times/day	0.54 (0.38-0.77)	0.003		
Proximal tooth cleaning frequency				
<1 time/day	1.00			
≥1 time/day	0.89 (0.72-1.09)	0.23		
Dental care frequency				
None or irregular	1.00			
Regular	0.60 (0.39-0.93)	0.02		
Exposure to cigarette smoking				
Never-smoker	1.00			
Moderate smoker	1.50 (1.16-1.93)	0.005		
Heavy smoker	2.13 (1.42-3.19)	0.002		
Weight status[a]				
Normal	1.00		1.00	
Overweight	0.86 (0.63-1.19)	0.35	0.99 (0.67-1.45)	0.96
Obese	0.72 (0.48-1.07)	0.09	1.01 (0.69-1.50)	0.91
Gingivitis				
≤20%	1.00			
21% to 59%	0.94 (0.61-1.44)	0.76		
≥60%	0.89 (0.52-1.53)	0.65		
Coronal DMFT scores	1.09 (1.07-1.12)	<0.001	1.11 (1.07-1.15)	<0.001
No. of retained teeth	0.96 (0.94-0.97)	<0.001	0.92 (0.89-0.95)	<0.001
No. of teeth with recession	1.06 (1.05-1.08)	<0.001	1.15 (1.15-1.22)	<0.001

IRR, incidence rate ratio; 95% CI, 95% confidence interval.
[a]Variables maintained in the final model independently of the *P*-value.

Discussion

This thesis was conducted to assess coronal and root caries and their risk indicators in a representative sample of adults and the elderly from Porto Alegre, South Brazil. Consistent with the latest nationwide survey performed in Brazil, the present findings highlights the high burden of coronal caries in adults and the elderly (15). The estimated prevalence was high in all age groups, which has been found in previous cross-sectional studies in several countries (19, 56, 57). We observed a higher mean DMFT score compared to worldwide data (19, 56), but the findings were similar to those of a recent South American study (57). In the present study population, the high coronal caries experience may be mainly attributed to the very high rate of tooth loss. Although the number of missing surfaces was low in adults aged 35-44 years, the mean DS score increased significantly in older individuals. Compared to the younger age group, the elderly age group had three times as many missing surfaces. Access to and use of specialized dental care continues to be limited in the Brazilian public health system; as a result, extraction is the only therapeutic option in many cases of advanced coronal caries. Thus, improvements in the oral health system should include coronal caries prevention in the adult and elderly population.

The combined influence of increased life expectancy (1), greater tooth retention in adults aged 35-44 years (8), and high prevalence of gingival recession (9) has increased the risk of root caries. Current data on the prevalence and extent of root caries vary significantly. The root caries prevalence ranges from 10% to 34.8% in adults aged 35-44 years (18, 21, 56) and from 18.2% to 89.7% in the elderly (17, 18, 20-22, 56). Furthermore, in adults aged 35-44 years, the mean DFS score ranges from 0.1 to 0.21 (18, 56), and in the elderly, the mean DFS score ranges from 0.21 to 3.8 (17, 18, 22, 56). In the present study, more than one-third of participants had root caries. These differing estimates for root caries are not explained by the number of retained teeth, but rather, are likely due to socio-demographic and methodological variations between the studies. Differences in the dental examination protocol may also explain the variation between our data and the 2010 Brazilian survey data (RCI of 4.0% *vs.* 2.7% for adults and 16.5% *vs.* 7.3 % in the elderly). In our study, all participants underwent tooth brushing and flossing before dental examination, which made it easier to diagnose root lesions and may have resulted in the higher prevalence rate.

Our findings highlight the distinct pattern of coronal and root caries distribution in this Brazilian population. Whereas the coronal caries prevalence remained stable with increasing age, the root caries prevalence increased two-fold in adults aged 45-59 years compared to younger individuals. This trend is consistent with previous reports indicating the need for effective measures toward root caries control in older people (18, 22). However, although the mean coronal DS score decreased with increasing age, the mean coronal DMFS score was higher than the mean root DFS score, highlighting the need for preventive strategies controlling both coronal and root caries in adults and the elderly.

In the present study, the maxillary and mandibular molars had the highest coronal caries experience. The mean coronal DMFS score for molars remained high but stable with increasing age, likely because the molars are commonly lost throughout life. An Australian study indicated that 60% of molars were missing in elderly individuals aged ≥60 years, and between 30% and 58% of the coronal molar surfaces had fillings (58). We also found that root caries was most frequently detected in the premolars in all age groups, which is consistent with previous studies of individuals aged 35-44 (18) and 25-74 years (21). Similarly, Marques et al. (16) found higher rates of root caries in the mandibular premolars of men and women aged 35-44 years and women aged 65-74 years. These findings are unsurprising given those of Susin et al. (59), who observed that the mandibular second premolars had the highest frequency of gingival recession of ≥3 mm in individuals aged 30-49 and ≥50 years. Notably, gingival recession is prerequisite for root caries development (10).

Dental caries is increasingly regarded as closely following a social gradient (60). Recently, a systematic review assessed the association between socioeconomic indicators and coronal caries in adults aged 19-60 years by analyzing 41 cross-sectional, prospective cohort, and ecological studies (26). Of these studies, 21 employed multivariate analyses, whereas the remaining studies did not adjust for confounding variables. The systematic review revealed a gradient with poorer socioeconomic conditions being associated with greater caries severity. Furthermore, a cross-sectional study of Greek adults and elderly (aged 35-44 and 65-74 years, respectively) showed that those with >12 years of education were less likely to have coronal caries after controlling socio-demographic risk variables (19). Consistent with these findings, the present study found a significant association between a high educational status and higher coronal DMFT scores by using a multivariate model adjusted for well-known socio-demographic, behavioral, and clinical factors for coronal caries. The effect of educational status on coronal caries may be explained by increasing evidences associating poor socioeconomic conditions with poor attitudes toward oral health, such as a high consumption of cariogenic carbohydrates (61) and a low perceived need for and utilization of dental services (62).

In our study, a high educational status was significantly associated with higher root DFT scores in adults and the elderly, consistent with a previous study where Thai individuals aged 60-74 years with more than 4 years of education were 139% more likely to have root caries after adjusting for sex, age, coronal DMFT scores, the number of retained teeth, and the number of surfaces with recession (17). Other studies found either no relationship or negative associations between educational status and root caries in older individuals after adjusting for basic socio-demographic characteristics (18, 19).

After adding the number of retained teeth, number of teeth with recession, and coronal DMFT scores to our risk model, the likelihood of root caries increased from 57% to 74% in individuals with a high educational status, while the association between an intermediate educational status and root caries was no longer observed. Of note, gingival recession has been shown to be significantly associated with educational status and root caries. A recent report used the same sample as our study (1,023 South Brazilian individuals aged ≥35 years) to determine the risk indicators for gingival recession, and showed that a high educational status was significantly associated with a higher likelihood of gingival recession of ≥5 mm when considering only buccal sites (9). With regard to the relationship between gingival recession and root caries, our results observed that a larger number of teeth with recession increased the probability of root caries by 18%, which is in agreement with previous cross-sectional study in the elderly from Sri Lanka (22). It is thus plausible that individuals with a high educational status are more likely to have gingival recession and consequently a higher chance of root caries.

The results of our multivariate analyses cannot comprehensively explain the social gradient associated with coronal and root caries experience. We used a cross-sectional design for the present study; hence, a cause-and-effect relationship could not be established. However, this type of study provides useful data for longitudinal investigations.

Increasing evidence suggests that dental caries could be classified according to its activity (28-32). This is an important concept that directly affects caries management. The present study showed coronal and root caries prevalences of 100% and 44.30%, respectively, using well-known caries experience criteria (modified DMFT index). The use of these epidemiological data to predict treatment should be done with caution because the data also comprised non-cavitated inactive lesions. When only non-cavitated and cavitated active lesions were included in the prevalence estimates, the prevalence of coronal and root caries decreased to 34.26% and 14.73%, respectively. However, it is important to emphasize that at least one-third of the study population showed caries activity. Thus, it may be concluded that a large number of adults and the elderly from Porto Alegre, Brazil require intervention (non-operative or operative treatment) to arrest disease progression and improve oral health.

Multivariate analyses were applied to identify risk indicators for coronal caries activity in this adult and elderly population. While sex, educational status, and exposure to cigarette smoking were not associated with coronal caries activity, poor oral hygiene habits and irregular dental care emerged as significant risk indicators for the outcome in both adjusted models. Gingivitis (≥60% of bleeding sites) also increased the likelihood of coronal caries activity. These findings highlight the significant impact of behavioral factors on the development and progression of coronal caries.

Exploratory analysis of our data indicated that increased age was significantly associated with higher coronal DMFT scores. This finding may reflect the difficulty of the elderly in mechanically removing plaque due to their diminished manual dexterity, impaired vision, and other debilitating conditions (63, 64). However, the same relationship was not found between age and coronal caries activity. The present study showed a gradual decrease in the mean number of coronal active lesions according to increased age, and the adjusted models indicated a lower likelihood of coronal caries activity in the elderly. These results may be explained, in part, by the larger proportion of biofilm stagnation areas that were already filled in adults and the elderly. Furthermore, cumulative de- and re-mineralization of the coronal surfaces occurs throughout life, which replaces the lost soluble minerals with minerals of higher acid resistance (65, 66). Thus, it is plausible to find a lower number of coronal active lesions in subjects aged ≥60 years.

Our previous analyses observed that the probability of root caries experience was affected primarily by the number of retained teeth, gingival recession, and coronal caries experience. Therefore, the present study carefully investigated the association between root caries activity and explanatory variables using two multivariable models. Although behavioral variables were significantly associated with the root caries activity in the first adjusted model, this relationship was not found after adding the number of retained teeth, number of teeth with recession, and coronal caries activity in the final adjusted model. Such variability between both multivariable models may have occurred because the behavioral variables were highly correlated with clinical characteristics, which may have directly influenced the associations.

The present study showed that coronal caries activity had the strongest association with the root caries activity of all risk indicators. Studies investigating the progression of caries lesions at various life stages observed that middle-aged people generally have a larger number of root caries lesions compared to younger subjects (67, 68). This finding may reflect the greater exposure of root surfaces to the oral environment in adults and the elderly (9, 59). Notably, increased age and gingival recession have been considered biological factors required for the onset of root caries (10, 69). This may suggest that root caries can be prevented by controlling coronal caries activity at a younger age before root surfaces are exposed. Comprehensive measures including oral hygiene, widespread use of fluoride, and dietary control should be included in a multifaceted strategy for coronal caries control (70).

In regards to weight status analysis, our findings showed that more than 50% of the study population was overweight or obese, which is consistent with reports suggesting that the prevalence of both conditions is likely to increase (41, 42). A high-sugar diet has been identified as potential contributor to the overweight and obesity epidemic (38, 39). Because dental caries is strongly associated with the sugar intake (37), a common risk prevention approach could be applied for both dental caries and excessive body weight. Over the past few years, many studies have tested the hypothesis that children and adolescents who are overweight or obese are at increased risk for dental caries, but conflicting results have been found (43-49). This could indicate that overweight and obesity are not associated with dental caries in younger populations. In fact, a population-based study including Brazilian schoolchildren aged 12 years did not find any relationship of overweight and obesity with the prevalence and extent of dental caries after adjusting for sex, socioeconomic status, and tooth brushing frequency (47).

This growing body of evidence regarding the relationship of overweight and obesity with dental caries should also include adults and older people for two reasons. Firstly, recent improvements in overall health status have increased the mean life expectancy (1) and retention of teeth throughout life (8). Secondly, the increased prevalence of overweight and obesity may be correlated with increased age (71). Our study assessed an adult and elderly population and found that overweight and obesity were not significantly associated with coronal and root caries experience. Similarly, using self-reported tooth loss as outcome, a study including 4,483 Brazilian civil servants aged ≥60 years showed no significant association with overweight and obesity in this age group (72).

Our findings contradicts the concept that high-sugar diet is a common risk factor for dental caries and excessive body weight. In fact, reports investigating the relationship between high sugar-sweetened beverage consumption and weight status have shown controversial results (38, 39, 73). A prospective study involving three separate cohorts that included 120,877 women and men with a 20-year follow-up in the United States indicated a potential role of sugar-sweetened beverage consumption in promoting long-term weight gain after applying multivariate models adjusted for age, baseline BMI for each period, and lifestyle factors (38).

Furthermore, a systematic review and meta-analysis including 32 prospective cohort studies and randomized clinical trials provide evidence that high sugar-sweetened beverage consumption promotes weight gain in children and adults (39). In contrast, a recent systematic review evaluating 14 observational studies published between 2001 and 2013 found that the relationship between sugar-sweetened beverage consumption and obesity risk was inconsistent for children, adolescents, and adults (73). Therefore, it is plausible to suggest that overweight and obesity may be associated with other types of diet. According to Brazilian data from the Telephone Monitoring System for Risk and Protection Factors for Chronic Diseases (VIGITEL), 53.5% of the participants aged ≥18 years ingested milk with significant fat content and 31% of the participants consumed fatty meat (74). This could explain, at least in part, the high prevalence of overweight and obesity in Brazil.

Our study has certain limitation. As described previously, our study was cross-sectional in nature. For this reason, the causal and temporal relationships of overweight and obesity with coronal and root caries experience remain unclear because it is not possible to determine which condition was firstly established. However, the present study provides useful data for further prospective cohort investigations.

Conclusions

* Coronal and root caries were highly prevalent in this Brazilian population. The coronal and root caries experience were also elevated. Molars and premolars were the teeth most frequently attacked by coronal and root caries, respectively.
* Educational status was a risk indicator for both coronal and root caries. Clear social gradients associated with coronal and root caries were observed, but with different directionalities. The likelihood of coronal caries decreased with a high educational status. Conversely, individuals with a high educational status should be considered at high risk for root caries.
* Caries activity was highly prevalent in adults and the elderly. Age, oral hygiene habits, dental care, gingivitis, and the number of retained teeth were risk indicators for coronal caries activity. Root caries activity was significantly associated with educational status, the number of retained teeth, and the number of teeth with gingival recession. Furthermore, coronal caries activity greatly increased the likelihood of root caries activity and should be targeted in preventive strategies during early life prior to exposure of root surfaces.
* Overweight and obesity were not associated with coronal and root caries experience. Thus, overweight and obese individuals should not be considered at high risk for both coronal and root caries.

Conclusions (in Portuguese)

* A cárie coronária e cárie radicular foram altamente prevalentes nesta população brasileira, e molares e pré-molares foram os dentes mais acometidos por cárie coronária e cárie radicular, respectivamente.
* O nível educacional foi um indicador de risco para ambas cárie coronária e cárie radicular. Gradientes sociais distintos foram observados. A probabilidade de cárie coronária diminuiu com um alto nível educacional. Em contraste, indivíduos com um alto nível educacional devem ser considerados em alto risco para cárie radicular.
* A atividade de cárie foi altamente prevalente em adultos e idosos. Idade, hábitos de higiene oral, acesso a serviços odontológicos, gengivite e número de dentes retidos foram indicadores de risco para atividade de cárie coronária. A atividade de cárie radicular foi significativamente associada com nível educacional, número de dentes retidos e número de dentes com recessão. Além disso, a atividade de cárie coronária aumentou significativamente a probabilidade de atividade de cárie radicular e deve ser incluída em estratégias preventivas durante idades precoces que antecedam a exposição das superfícies radiculares.
* Sobrepeso e obesidade não foram significativamente associados com a experiência de cárie radicular e cárie coronária. Assim, os indivíduos com sobrepeso e obesos não devem ser considerados em alto risco para ambas cárie coronária e cárie radicular.

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Appendices

* **Paper I.** Prevalence, extent, and intra-oral distribution of coronal and root caries among adults and the elderly from South Brazil: a population-based study.

* **Paper II.** Educational status as a risk indicator for coronal and root caries among adults and the elderly from South Brazil.

* **Paper III.** Coronal and root caries activity among adults and the elderly from South Brazil: prevalence estimates and assessment of risk indicators.

* **Paper IV.** Overweight and obesity are not associated with coronal and root caries experience in adults and the elderly.

Paper 1

Prevalence, extent, and intra-oral distribution of coronal and root caries among adults and the elderly from South Brazil: a population-based study

Prevalence, extent, and intra-oral distribution of coronal and root caries among adults and the elderly from South Brazil: a population-based study

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Abstract

Background

The rates of dental caries have changed over time, with a decline in the proportion of coronal caries and an increase in the rates of root caries becoming apparent. Furthermore, there is a lack of population-based studies combining data on coronal and root caries, which may help to better understand oral health initiatives in older individuals. Therefore, the purpose of this study was to assess the prevalence, extent, and intra-oral distribution of coronal and root caries in adults and the elderly from Porto Alegre, South Brazil.

Methods

This cross-sectional study used a multistage sampling strategy to draw a representative sample of 1,023 individuals aged ≥35 years. Questionnaires were used to collect demographic data. Oral examination assessed gingival recession and coronal and root caries. Survey commands were used to calculate coronal and root caries estimates and 95% confidence intervals (95% CIs).

Results

The coronal and root caries prevalence was 99.73% (95% CI 99.31-100.00) and 41.14% (95% CI 37.57-44.72), respectively. The mean coronal DMFT and root DFT scores was 18.73 (95% CI 18.29-19.17) and 1.15 (95% CI 0.95-1.34), respectively. The mean coronal DMFS and root DFS scores was 66.56 (95% CI 63.30-69.83) and 1.49 (95% CI 1.25-1.73), respectively. The mean coronal DMFS score was significantly higher in the older age groups compared to individuals aged 35-44 years. The mean coronal DS score significantly decreased between individuals aged 35-44 years and those aged 45-59 and ≥ 60 years. The mean coronal MS score significantly increased with age. The root caries estimates were significantly higher in individuals aged 45-59 and ≥60 years compared to those aged 35-44 years. Molars and premolars were the teeth most affected by coronal and root caries, respectively.

Conclusions

Our findings indicated high prevalence and extent of both coronal and root caries in this Brazilian population. Thus, besides the need for control measures of root caries, oral health initiatives must also continue to target coronal caries in adults and the elderly.

Keywords

Dental caries, root caries, DMF index, epidemiology, prevalence, adult

Background

Children and adolescents are the most frequently examined groups in studies of dental caries, while reports investigating the adult and elderly populations are less prevalent. Globally, the prevalence of coronal caries is high among adults and elderly individuals, as the disease affects almost 100% of the population in a majority of the countries [1, 2]. The coronal caries experience varies substantially in different parts of the world as well as within the same region or country [1-3]. A number of public health measures including effective use of fluorides and improved access and use of dental services have resulted in a decline in the occurrence of coronal caries over the past few decades. In Brazil, a decrease in the rates of coronal caries in adults aged 35-44 years was observed between 2003 and 2010 [4, 5]. However, the mean coronal DMFT score remains high in both the 35-44 and 65-74 year age groups.

Recent improvements in overall health status have increased the mean life expectancy and retention of teeth throughout life, but have also elevated the prevalence of gingival recession, which may increase the likelihood of root caries. The 2010 Brazilian nationwide survey showed that less than 20% of adults were affected by root caries and no more than 11% of the exposed root surfaces were decayed or filled [6]. In contrast, higher rates were reported by studies conducted in Thailand [7], China [8], Greece [9], England [10], Germany [11] and Sri Lanka [12]. Prospective cohort studies reported that older individuals exhibit higher rates of new root caries [13, 14]. Thus, there is evidence to suggest that root caries is gradually becoming a public health concern among adults and aged individuals.

The rates of dental caries have changed over time, with a decline in the proportion of coronal caries and an increase in the rates of root caries becoming apparent. Therefore, it is plausible to suggest the need for periodic studies exploring both diseases. Furthermore, there is a lack of population-based studies combining data on coronal and root caries, which may help to better understand oral health initiatives in older individuals. Therefore, the purpose of this study was to assess the prevalence, extent, and intra-oral distribution of coronal and root caries in a representative sample of adult and the elderly from Porto Alegre, South Brazil.

Methods

This cross-sectional study was part of the Caries-Perio Collaboration Survey, which included 1,225 individuals aged ≥35 years from Porto Alegre, South Brazil. The fieldwork was conducted from June 2011 to June 2012.

Sample size calculation and sampling strategy

This was a multi-disciplinary study measuring a variety of oral outcomes; therefore, the sample size calculation used a 50% prevalence (worst-case scenario) for any oral condition assessed. A multistage sampling strategy was employed but was estimated to yield approximately 50% inefficiency. A standard formula for prevalence estimation was applied adjusting the sample size for this design effect. Assuming a ±4% precision level and a 95% confidence interval (CI), a sample size of 940 individuals was estimated.

This study used a multistage stratified random sampling strategy (Figure 1). In the first stage, the city was divided into 86 neighbourhoods (primary sampling units [PSUs]). The PSUs were then divided into high- versus low-income strata. PSUs were randomly selected in proportion to the number of PSUs in each stratum. In the second stage, random sectors (map areas comprising approximately 300 households) were selected in proportion to the total number of sectors in each PSU; 48 of the 373 elegible sectors were selected. In the third and final stage, consecutive households were selected (beginning at the sector starting point and continuing until the sector sample size was reached). The number of individuals to be selected within each sector was estimated based on the proportional distribution of the sample size according to the number of individuals aged ≥35 years who were living in each sector. All household members aged ≥35 years were eligible for the study. Individuals whose mental or systemic health conditions did not allow them to perform the interview or the clinical examination were excluded. Non-residential establishments such as nursing homes and commercial establishments were not approached. Detailed information about the methodology used has been already described [15].

Data collection

Study participants were interviewed and underwent an oral examination in their own homes, performed by three trained and calibrated researchers (FSR, MSM and RSAC). A structured questionnaire comprising questions regarding demographic characteristics was used. A test-retest approach was performed to assess the reliability of the questionnaire (unweighted Cohen’s kappa varied from 0.91 to 0.99).

The clinical examination was conducted in the supine position. Field equipment included portable lights, an air compressor, plane mouth mirrors, and periodontal probes. Two examiners (FSR and RSAC) assessed gingival recession, which was defined as the distance from the cement-enamel junction to the free gingival margin. After teeth cleaning and drying, a single examiner (MSM) assessed coronal and root caries by determining whether the tooth surfaces were sound, decayed, missing, and filled. Decayed surfaces were classified into non-cavitated (coronal caries, opaque and dull-white surface with surface continuity; root caries, opaque and dull-yellow surface with surface continuity) and cavitated. Intra-examiner reliability for the caries assessment was conducted by repeated examinations in 5% of the sample within a 1-week interval. The lowest unweighted Cohen’s kappa was 0.77. Similarly, intra-examiner reliability for the gingival recession assessment revealed weighted (±1 mm) Cohen’s kappa values of 0.98 and 0.99, and an inter-examiner value of 0.91.

Non-response analysis

In statistical analyzes, non-response was accounted for by using the inverse probability weighting strategy [16]. A non-response weight variable considering eligible and actual participants as well as the distributions of age, sex, and educational status was generated for each sector.

A total of 375 (23.43%) individuals did not participate in the Caries-Perio Collaboration Survey. Reasons for non-participation are described in Figure 1. Some questions in the questionnaire were answered by 219 (58.40%) non-respondents; these data were compared with data from the individuals included in the final sample. The non-respondents were slightly older than the respondents (mean age 55.50 ± 11.80 *vs.* 52.60 ± 11.80 years, P = 0.001), and the percentage of individuals with a high educational status was significantly higher in the non-respondent group than in the respondent group. No significant differences regarding the proportion of men versus women and the self-reported mean number of missing teeth were found between the two groups.

Data analysis

All dentate individuals (*n* = 1,023) from the Caries-Perio Collaboration Survey were included in the present sub-study. Coronal caries was analyzed according to the (1) extent, defined as the number of decayed, missing, and filled surfaces (DMFS) or teeth (DMFT); and (2) prevalence, defined as the percentage of individuals with at least one decayed, missing, or filled tooth (DMFT = 0 or DMFT ≥1). Root caries was analyzed according to the (1) extent, defined as the number of decayed and filled surfaces (DFS) or teeth (DFT); (2) prevalence, defined as the percentage of individuals with at least one decayed or filled tooth (DFT = 0 or DFT ≥1); and (3) Root Caries Index (RCI), defined as the percentage of teeth with an exposed root surface (gingival recession of ≥1 mm) that is decayed or filled [17]. Participant age was categorized as 35-44, 45-59, or ≥60 years.

Data analysis was performed using STATA software (Stata 11.1 for Windows, Stata Corporation, College Station, Texas, USA). A sampling weight variable was computed using census information provided by the Brazilian Institute of Geography and Statistics. Complex survey commands were applied to account for cluster correlations expected for the multistage sampling strategy used in this study. Prevalence and extent estimates and the RCI were reported as means and 95% CIs. Pair-wise comparisons of crude estimates were performed using the Wald test. The significance level was set at 5%.

Ethical considerations

The study protocol was approved by the Federal University of Rio Grande do Sul Research Ethics Committee (19794/11). Signed informed consent was obtained from all study participants.

Results

A total of 1,600 individuals were eligible for the Caries-Perio Collaboration Survey (Figure 1). Of them, 375 (23.43%) did not participate in the survey (non-respondents), resulting in a final sample of 1,225 (76.56%) individuals. The present sub-study comprised all dentate individuals (n = 1,023), among which 398 (38.91%) were men and 625 (61.09%) were women aged 35-95 years (Table 1).

As shown in Table 2, the overall coronal caries prevalence was 99.73% (95% CI 99.31-100.00) and remained stable among the age groups. The mean coronal DMFT score was significantly higher in the older age groups compared to individuals aged 35-44 years.

As shown in Table 3, the overall root caries prevalence was 41.14% (95% CI 37.57-44.72). The root caries prevalence, mean root DFT score, and RCI were significanlty higher in individuals aged 45-59 and ≥60 years compared to those aged 35-44 years. The RCI was four-fold greater in individuals aged ≥60 years than in those aged 35-44 years.

Table 4 shows the mean coronal DMFS and root DFS scores according to age. The mean coronal DMFS and root DFS scores were 66.56 (95% CI 63.30-69.83) and 1.49 (95% CI 1.25-1.73), respectively. The mean coronal DS score significantly decreased between individuals aged 35-44 years and those aged ≥60 years. The mean coronal MS score significantly increased with age. The mean root DS and FS scores were significantly higher in individuals aged 45-59 and ≥60 years compared to those aged 35-44 years.

The pattern of intra-oral distribution of coronal caries was similar among the age groups (Figure 2). In all age groups, the molars were the most frequently teeth affected by coronal caries in both the maxillary and mandibular arches. As shown in Figure 3, the RCI was highest in the premolars of both the maxillary and mandibular arches in every age group.

Discussion

This study was conducted to assess the prevalence, extent, and intra-oral distribution of coronal and root caries in adults aged ≥35 years from Porto Alegre, South Brazil. The study population showed a nearly 100% coronal caries prevalence and an approximately 41% root caries prevalence. The coronal DMFT and root DFT scores were also elevated. The molars and premolars were the most frequently teeth affected by coronal and root caries, respectively. The major finding of this analysis was that while high estimates for root caries have been reported in adults and the elderly, coronal caries remains a pressing public health concern.

Consistent with the latest nationwide survey performed in Brazil, the present study highlights the high burden of coronal caries in adults and the elderly [5]. The estimated prevalence was high in all age groups, which has been found in previous cross-sectional studies in several countries [9, 18, 19]. We observed a higher mean DMFT score compared to worldwide data [9, 18], but the findings were similar to those of a recent South American study [19]. In this study population, the high coronal caries experience may be mainly attributed to the very high rate of tooth loss. Although the number of missing surfaces was low in adults aged 35-44 years, the mean DS score increased significantly in older individuals. Compared to the younger age group, the elderly age group had three times as many missing surfaces. Access to and use of specialized dental care continues to be limited in the Brazilian public health system; as a result, extraction is the only therapeutic option in many cases of advanced coronal caries. Thus, improvements in the oral health system should include coronal caries prevention in the adult and elderly population.

The combined influence of increased life expectancy [20], greater tooth retention in adults aged 35-44 years [21], and high prevalence of gingival recession [22] has increased the risk of root caries. Current data on the prevalence and extent of root caries vary significantly. The root caries prevalence ranges from 10% to 34.8% in adults aged 35-44 years [8, 11, 18] and from 18.2% to 89.7% in the elderly [7, 8, 10-12, 18]. Furthermore, in adults aged 35-44 years, the mean DFS score ranges from 0.1 to 0.21 [8, 18], and in the elderly, the mean DFS score ranges from 0.21 to 3.8 [7, 8, 12, 18]. In the present study, more than one-third of participants had root caries. These differing estimates for root caries are not explained by the number of retained teeth, but rather, are likely due to socio-demographic and methodological variations between the studies. Differences in the dental examination protocol may also explain the variation between our data and the 2010 Brazilian survey data (RCI of 4.0% *vs.* 2.7% for adults and 16.5% *vs.* 7.3 % in the elderly). In our study, all participants underwent tooth brushing and flossing before dental examination, which made it easier to diagnose root lesions and may have resulted in the higher prevalence rate.

Our findings highlight the distinct pattern of coronal and root caries distribution in this Brazilian population. Whereas the coronal caries prevalence remained stable with increasing age, the root caries prevalence increased two-fold in adults aged 45-59 years compared with those younger. This trend is consistent with previous reports indicating the need for effective measures toward root caries control in older people [8, 12]. However, although the mean coronal DS score decreased with increasing age, the mean coronal DMFS score was higher than the mean root DFS score, highlighting the need for preventive strategies controlling both coronal and root caries in adults and the elderly.

In the present study, the maxillary and mandibular molars had the highest coronal caries experience. The mean coronal DMFS score for molars remained high but stable with increasing age, likely because the molars are commonly lost throughout life. An Australian study indicated that 60% of molars were missing in elderly individuals aged ≥60 years, and between 30% and 58% of the coronal molar surfaces had fillings [23]. We also found that root caries were most frequently detected in the premolars in all age groups, which is consistent with previous studies of individuals aged 35-44 [8] and 25-74 years [11]. Similarly, Marques et al. [6] found higher rates of root caries in the mandibular premolars of men and women aged 35-44 years and women aged 65-74 years. These findings are unsurprising given those of Susin et al. [24], who observed that the mandibular second premolars had the highest frequency of gingival recession of ≥3 mm in individuals aged 30-49 and ≥50 years. Notably, gingival recession is prerequisite for root caries development [17].

Conclusions

The present study compared data on coronal and root caries among adults and the elderly from South Brazil and found high prevalence and extent of both coronal and root caries. Thus, besides the need for control measures of root caries, oral health initiatives must also continue to target coronal caries in adults ≥35 years.

List of abbreviations

95% CI = 95% confidence interval

PSU = primary sampling unit

DMFT = decayed, missing, and filled teeth

DMFS = decayed, missing, and filled surface

DFT = decayed and filled teeth

DFS = decayed and filled surface

DS = decayed surface

MS = missing surface

FS = filled surface

RCI = root caries index

Competing interests

The authors declare that they have no proprietary, financial, professional, or other personal interest of any kind in any product, service, or company that could influence the position presented in or the review of the manuscript "**Prevalence, extent, and intra-oral distribution of coronal and root caries among adults and the elderly from South Brazil: a population-based study".**

Author's contributions

MSM contributed substantially to the conception and design of the project, participated in the data collection, reviewed the literature, and prepared the text. FSR and RSAC participated in the data collection. MM, JJJ, and ANH participated in the design and coordination of the project and helped to draft the manuscript. All authors have read and approved the final manuscript.

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Figure legends

Figure 1. Flowchart of sampling strategy and response rate (PSU = primary sampling unit).

Figure 2. Mean coronal DMFT score according to tooth type and age.

Figure 3. Root Caries Index (%) according to tooth type and age.

Figure 1

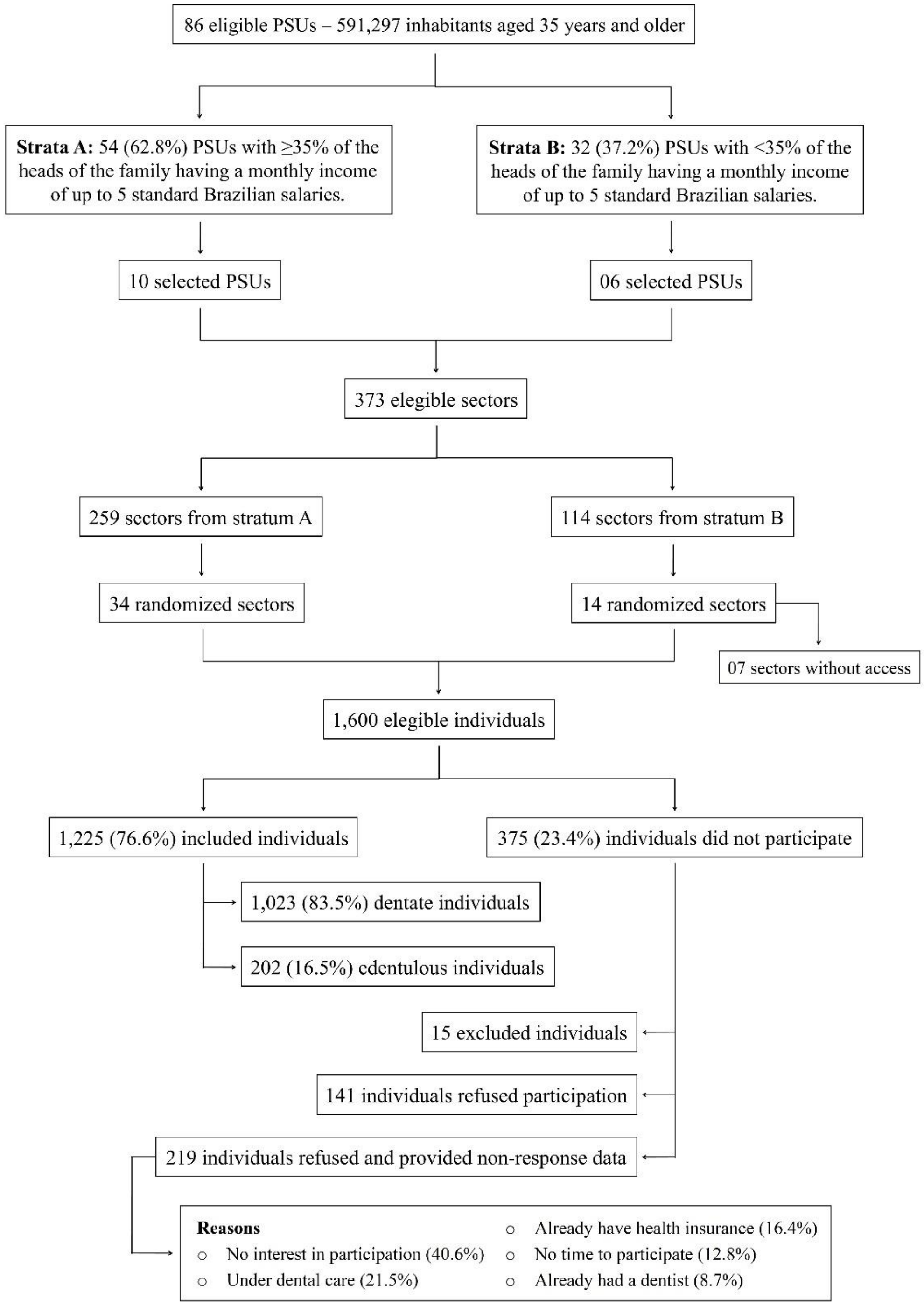

86 eligible PSUs – 591,297 inhabitants aged 35 years and older
Strata A: 54 (62.8%) PSUs with ≥35% of the heads of the family having a monthly income of up to 5 standard Brazilian salaries.
Strata B: 32 (37.2%) PSUs with <35% of the heads of the family having a monthly income of up to 5 standard Brazilian salaries.
10 selected PSUs
06 selected PSUs
373 elegible sectors
259 sectors from stratum A
114 sectors from stratum B
34 randomized sectors
14 randomized sectors
07 sectors without access
1,600 elegible individuals
1,225 (76.6%) included individuals
375 (23.4%) individuals did not participate
1,023 (83.5%) dentate individuals
202 (16.5%) edentulous individuals
15 excluded individuals
141 individuals refused participation
219 individuals refused and provided non-response data
Reasons
No interest in participation (40.6%)
Under dental care (21.5%)
Already have health insurance (16.4%)
No time to participate (12.8%)
Already had a dentist (8.7%)

Figure 2

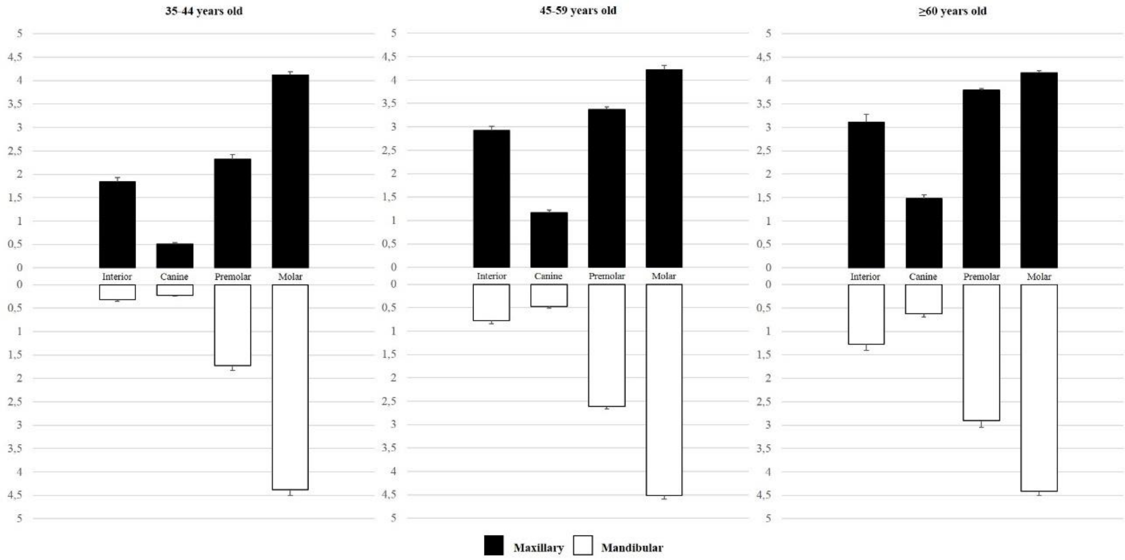
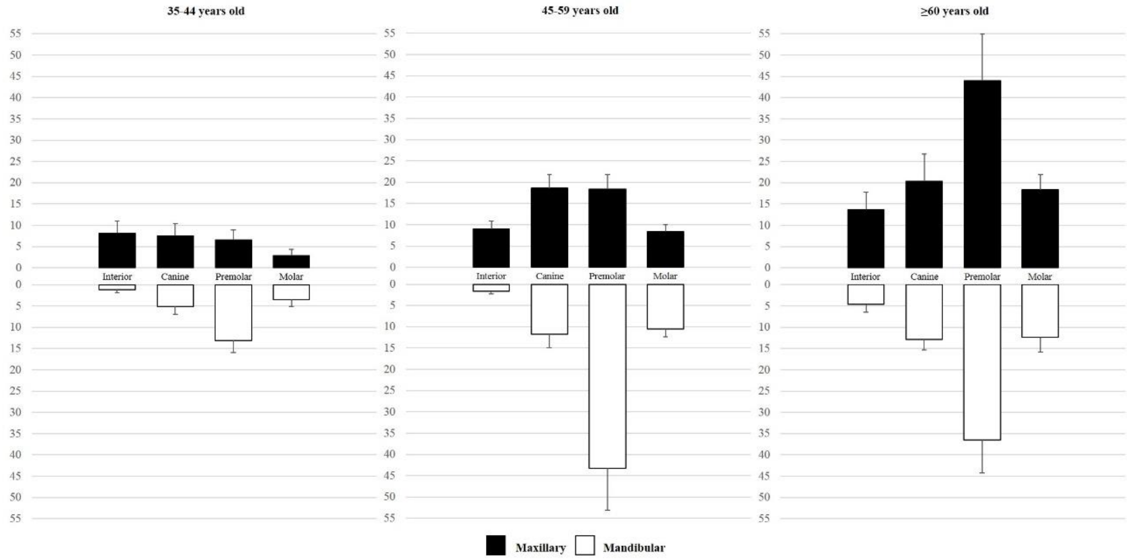

35-44 years old
45-59 years old
≥60 years old
Interior
Canine
Premolar
Molar
Maxillary
Mandibular

Figure 3


35-44 years old
45-59 years old
≥60 years old
0
5
10
15
20
25
30
35
40
45
50
55
Interior
Canine
Premolar
Molar
Maxillary
Mandibular

Tables

Table 1. Study sample distribution according to age and sex.

Age, years	*n*	Males, %	Females, %
35-44	279	38.70	61.29
45-59	479	40.50	59.49
≥60	265	36.22	63.77
Total	1,023	38.91	61.09

Table 2. Mean coronal DMFT score and the percentage of individuals with coronal DMFT>0 according to age.

Age, years	DMFT, mean (95% CI)	DMFT>0, % (95% CI)
35-44	15.48 (14.59-16.36)[a]	99.59 (98.74-1.00)[a]
45-59	20.09 (19.54-20.63)[b]	99.70 (99.09-1.00)[a]
≥60	21.78 (20.79-22.77)[c]	100.00[a]
Total	18.73 (18.29-19.17)	99.73 (99.31-1.00)

95% CI = 95% confidence interval.

Different letters indicate a statistically significant difference between categories using the Wald test ($P \leq 0.05$).

Table 3. Mean root DFT score, the percentage of individuals with root DFT>0, and the Root Caries Index (RCI) according to age.

Age, years	DFT, mean (95% CI)	DFT>0, % (95% CI)	RCI, % (95% CI)
35-44	0.57 (0.35-0.79)[a]	24.37 (20.00-28.73)[a]	3.47 (2.15-4.79)[a]
45-59	1.40 (1.06-1.75)[b]	49.40 (41.76-57.05)[b]	11.62 (8.57-14.66)[b]
≥60	1.66 (1.26-2.06)[b]	54.86 (45.46-64.26)[b]	15.60 (10.74-20.47)[b]
Total	1.15 (0.95-1.34)	41.14 (37.57-44.72)	9.46 (7.67-11.26)

95% CI = 95% confidence interval.
Different letters indicate a statistically significant difference between categories using the Wald test ($P \leq 0.05$).

Table 4. Mean coronal DMFS and root DFS scores according to age.

	35-44 years old	45-59 years old	≥60 years old	Total
	CC, mean (95% CI)	CC, mean (95% CI)	CC, mean (95% CI)	CC, mean (95% CI)
DS				
Non-cavitated	0.54 (0.38-0.70)[a]	0.26 (0.05-0.47)[b]	0.05 (0.00-0.12)[b]	0.32 (0.20-0.44)
Dark shadowed*	0.54 (0.38-0.69)[a]	0.21 (0.12-0.29)[b]	0.15 (0.00-0.31)[b]	0.32 (0.22-0.42)
Cavitated	6.91 (5.83-8.00)[a]	6.74 (5.62-7.86)[a]	4.49 (3.70-5.27)[b]	6.28 (5.64-6.92)
MS	24.24 (20.27-28.21)[a]	49.38 (43.58-55.17)[b]	71.28 (63.86-78.70)[c]	44.93 (40.93-48.94)
FS	12.56 (9.94-15.18)[a]	18.00 (13.90-22.10)[b]	14.11 (11.49-16.72)[a]	15.02 (12.43-17.60)
DMFS	44.27 (40.75-47.79)[a]	74.39 (69.94-78.85)[b]	89.95 (82.62-97.27)[c]	66.56 (63.30-69.83)
	RC, mean (95% CI)	RC, mean (95% CI)	RC, mean (95% CI)	RC, mean (95% CI)
DS				
Non-cavitated	0	0	0	0
Cavitated	0.58 (0.38-0.77)[a]	1.06 (0.75-1.36)[b]	1.21 (0.71-1.71)[b]	0.91 (0.69-1.13)
FS	0.11 (0.04-0.18)[a]	0.80 (0.32-1.28)[b]	0.97 (0.63-1.30)[b]	0.58 (0.32-0.83)
DFS	0.69 (0.45-0.93)[a]	1.86 (1.42-2.30)[b]	2.18 (1.63-2.73)[b]	1.49 (1.25-1.73)

CC = coronal caries; RC = root caries.
*Surfaces with or without enamel breakdown.
Different letters indicate a statistically significant difference between categories of age using the Wald test ($P \leq 0.05$).

Paper II

Educational status as a risk indicator for coronal and root caries among adults and the elderly from South Brazil

Educational status as a risk indicator for coronal and root caries among adults and the elderly from South Brazil

Running head: Educational status and coronal and root caries

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Abstract

Objectives: To assess the association between educational status and coronal and root caries in adults and the elderly from South Brazil. *Methods:* This cross-sectional study used a multistage sampling strategy to draw a representative sample of 1,023 individuals aged ≥35 years. Questionnaires were used to collected data on socio-demographic characteristics, oral hygiene habits, dental care, and smoking. Oral examination assessed gingival bleeding, gingival recession, and coronal and root caries experience. Survey negative binomial regression models were used for data analysis (incidence rate ratio/95% confidence interval). *Results:* The mean coronal DMFT and root DFT scores were 18.73 (95% CI 18.29-19.17) and 1.15 (95% CI 0.95-1.34). Individuals aged 45-59 years (IRR 1.29, 95% CI 1.19-1.40) or ≥60 years (IRR 1.39, 95% CI 1.29-1.49) and women (IRR 1.09, 95% CI 1.04-1.14) were more likely to have coronal caries. The likelihood of coronal caries decreased with high educational status (IRR 0.88, 95% CI 0.78-0.99) and proximal tooth cleaning frequency (IRR 0.94, 95% CI 0.91-0.97). Individuals with higher coronal DMFT scores (IRR 1.11, 95% CI 1.07-1.14) and a larger number of teeth with recession (IRR 1.18, 95% CI 1.15-1.22) were more likey to have root caries. The likelihood of root caries decreased with a higher tooth brushing frequency (IRR 0.75, 95% CI 0.59-0.96) and a larger number of retained teeth (IRR 0.92, 95% CI 0.89-0.95). A high educational status increased the probability of root caries by 74% (IRR 1.74, 95% CI 1.11-2.72). *Conclusions:* Educational status was a risk indicator for both coronal and root caries in this Brazilian population. However, adults and the elderly with a high educational status should only be considered at high risk for root caries.

Introduction

When comparing data from the 2003 and 2010 Brazilian nationwide surveys, significant decreases in rates of coronal caries were recorded in the adult population (1). However, striking disparities by socioeconomic backgrounds are still observed. A recent systematic review showed an inverse relationship between socioeconomic indicators and coronal caries in adults aged 19-60 years (2). Therefore, strategies aimed at preventing coronal caries should be implemented in lower socioeconomic groups.

On the other hand, the relationship between socioeconomic indicators and root caries is poorly understood and cross-sectional studies have reported conflicting results (3-5). In the risk analyses, educational status has emerged as one of the most frequently used socioeconomic indicators for root caries as it is stable and is established in early adulthood. A study examining Chinese individuals aged 35-44 and 65-74 years showed no relationship between educational status and root caries (4). Mamai-Homata et al. (5) found similar results among an elderly Greek population aged 65-74 years, but not among Greek adults in the 35-44 age range. The latter group showed that adults with low educational status were more likely to have root caries. In contrast, Nicolau et al. (3) showed that Thai individuals older than 60 years of age and with high educational status were most likely to have root caries. Although these studies have used multivariate risk assessment models that were adjusted for a wide range of covariates, only one report took into account the potential role of clinical outcomes in the development of root caries (3). Furthermore, there is evidence to suggest that the number of retained teeth (6), number of exposed root surfaces (7) and coronal caries status (2) are all significantly associated with different social conditions.

Given the inconsistent results observed in the literature and the need to model data using comprehensible theoretical framework, the aim of this study was to assess the association between educational status and root caries in adults and the elderly from Porto Alegre, South Brazil. We focused our analysis on comparing the social gradients for coronal and root caries.

Materials and methods

This cross-sectional study was part of the Caries-Perio Collaboration Survey, which included 1,225 individuals aged ≥35 years from Porto Alegre, South Brazil. The fieldwork was conducted from June 2011 to June 2012. The study protocol was approved by the Federal University of Rio Grande do Sul Research Ethics Committee (19794/11). Signed informed consent was obtained from all study participants.

Sample size calculation

This was a multi-disciplinary study measuring a variety of oral outcomes; therefore, the sample size calculation used a 50% prevalence (worst-case scenario) for any oral condition assessed. A multistage sampling strategy was employed but was estimated to yield approximately 50% inefficiency. A standard formula for prevalence estimation was applied adjusting the sample size for this design effect. Assuming a ±4% precision level and a 95% confidence interval (CI), a sample size of 940 individuals was estimated. The minimum size of this sample to provide 80% statistical power and identify an odds ratio of 1.5 and/or a risk ratio of 1.2 was estimated to be 816 individuals (8). The calculation was based on the assumption that 50% of the unexposed population and 60% of the exposed population would have the outcome of interest, with an α equal to 0.05 and a β equal to 0.20.

Sampling strategy

This study used a multistage stratified random sampling strategy (Figure 1). In the first stage, the city was divided into 86 neighbourhoods (primary sampling units [PSUs]). The PSUs were then divided into high- versus low-income strata. PSUs were randomly selected in proportion to the number of PSUs in each stratum. In the second stage, random sectors (map areas comprising approximately 300 households) were selected in proportion to the total number of sectors in each PSU; 48 of the 373 elegible sectors were selected. In the third and final stage, consecutive households were selected (beginning at the sector starting point and continuing until the sector sample size was reached). The number of individuals to be selected within each sector was estimated based on the proportional distribution of the sample size according to the number of individuals aged ≥35 years who were living in each sector. All household members aged ≥35 years were eligible for the study. Individuals with mental or systemic health conditions that precluded the realization of interviews or clinical examinations were excluded. Non-residential establishments such as nursing homes and commercial establishments were not approached. Detailed information about the methodology used has been already described (9).

Data collection

Study participants were interviewed and underwent an oral examination in their own homes, performed by three trained and calibrated researchers (FSR, MSM and RSAC). A structured questionnaire comprising questions regarding socio-demographic characteristics, oral hygiene habits, dental care, and smoking was used. A test-retest approach was performed to assess the reliability of the questionnaire (unweighted Cohen's kappa varied from 0.91 to 0.99).

The clinical examination was conducted in the supine position. Field equipment included portable lights, an air compressor, plane mouth mirrors, and periodontal probes. Two examiners (FSR and RSAC) performed the gingival examination. Gingivitis was assessed using the gingival bleeding index (10). Gingival recession was defined as the distance from the cement-enamel junction to the free gingival margin. After teeth cleaning and drying, a single examiner (MSM) assessed coronal and root caries by determining whether the tooth surfaces were sound, decayed, missing, and filled. Decayed surfaces were classified into non-cavitated (coronal caries, opaque and dull-white surface with surface continuity; root caries, opaque and dull-yellow surface with surface continuity) and cavitated. Intra-examiner reliability for the caries assessment was conducted by repeated examinations in 5% of the sample within a 1-week interval. The lowest unweighted Cohen's kappa was 0.77. Similarly, intra-examiner reliability for the gingival recession assessment revealed weighted (±1 mm) Cohen's kappa values of 0.98 and 0.99, and an inter-examiner value of 0.91.

Non-response analysis

In statistical analyses, non-response was accounted for by using the inverse probability weighting strategy (11). A non-response weight variable considering eligible and actual participants as well as the distributions of age, sex, and educational status was generated for each sector.

A total of 375 (23.43%) individuals did not participate in the Caries-Perio Collaboration Survey. Reasons for non-participation are described in Figure 1. Some questions in the questionnaire were answered by 219 (58.40%) non-respondents; these data were compared with data from the individuals included in the final sample. The non-respondents were slightly older than the respondents (mean age 55.50 ± 11.80 *vs.* 52.60 ± 11.80 years, $P = 0.001$), and the percentage of individuals with a high educational status was significantly higher in the non-respondent group than in the respondent group. No significant differences regarding the proportion of men versus women and the self-reported mean number of missing teeth were found between the two groups.

Data analysis

All dentate individuals (*n* = 1,023) from the Caries-Perio Collaboration Survey were included in the present sub-study. The primary outcomes were the mean coronal decayed, missing, and filled teeth (DMFT) score and the mean root decayed and filled teeth (DFT) score. The prevalence of coronal caries was defined as the percentage of individuals with at least one decayed, missing, or filled surface. The prevalence of root caries was defined as the percentage of individuals with at least one decayed or filled surface.

Participant age was categorized as 35-44, 45-59, or ≥60 years. Educational status was based on the number of years of education and was categorized as low (0-8 years), intermediate (9-11 years), or high (>11 years). Tooth brushing and proximal tooth cleaning frequency were dichotomized as ≤1 time/day versus ≥2 times/day and <1 time/day versus ≥1 time/day, respectively. Dental care in the last 3 years was dichotomized as irregular (no dental visit or visits only for emergencies) versus regular (visits for prevention with a frequency of ≥2 times/year). Former and current smokers were considered to have had exposure to cigarette smoking. The number of packs of cigarettes consumed in a lifetime (pack-years) was calculated by multiplying the number of cigarettes consumed per day by the years of habit, divided by 20. Individuals were classified as never-smokers (0 pack-years), moderate smokers (<20 pack-years), or heavy smokers (≥20 pack-years). Gingivitis was categorized according to the percentage of bleeding sites on probing (≤20%, 21% to 59%, and ≥60%). The number of retained teeth and number of teeth with recession of ≥1 mm were modeled as continuous variables.

Data analysis was performed using STATA software (Stata 11.1 for Windows, Stata Corporation, College Station, Texas, USA). A sampling weight variable was computed using census information provided by the Brazilian Institute of Geography and Statistics. Complex survey commands were applied to account for cluster correlations expected for the multistage sampling strategy used in this study. Pair-wise comparisons of crude estimates were performed using the Wald test. The significance level was set at 5%. Survey negative binomial regression models were applied to assess the association between educational status and coronal and root caries experience. Estimates were adjusted for socio-demographic and behavioral variables (adjusted model 1). In the adjusted model 2, clinical variables were added to the analysis. A preliminary analysis using univariate models was performed, and variables showing associations with a $P<0.25$ were added to the multivariate models. Maintenance of variables in the final model was determined by a combination of a $P<0.05$ and analyses of confounders and interactions (12). Incidence rate ratios (IRR) and 95% CIs were estimated and reported.

Results

A total of 1,600 individuals were eligible for the Caries-Perio Collaboration Survey (Figure 1). Of them, 375 (23.43%) did not participate in the survey (non-respondents), resulting in a final sample of 1,225 (76.56%) individuals. The present sub-study comprised all dentate individuals (n = 1,023), among which 398 (38.91%) were men and 625 (61.09%) were women aged 35-95 years.

The overall prevalence rates of coronal and root caries was 99.73% (95% CI 99.31-1.00) and 41.14% (95% CI 37.57-44.72), respectively. As shown in Table 1, the mean coronal DMFT and root DFT scores was 18.73 (95% CI 18.29-19.17) and 1.15 (95% CI 0.95-1.34), respectively. Coronal DMFT scores significantly differed according to sex, age, educational status, proximal tooth cleaning frequency, dental care frequency, and exposure to cigarette smoking. Root DFT scores significantly differed according to sex, age, tooth brushing frequency, dental care frequency, and exposure to cigarette smoking.

In the multivariate model, coronal caries experience was associated with sex, age, educational status, and proximal tooth cleaning (Table 2). An increased likelihood of coronal caries was observed for individuals aged 45-59 years (IRR 1.29, 95% CI 1.19-1.40) and ≥60 years (IRR 1.39, 95% CI 1.29-1.49) and among women (IRR 1.09, 95% CI 1.04-1.14). A higher proximal tooth cleaning frequency was significantly associated with a lower probability of coronal caries (IRR 0.94, 95% CI 0.91-0.97). The likelihood of coronal caries was lower for participants with a high educational status than for those with a low educational status (IRR 0.88, 95% CI 0.78-0.99).

Table 3 shows the assocation between the mean root DFT score and explanatory variables. Individuals aged 45-59 years (IRR 2.21, 95% CI 1.45-3.38) or ≥60 years (IRR 2.81, 95% CI 2.13-3.70), and those with a lower tooth brushing frequency (IRR 0.68, 95% CI 0.48-0.95), irregular dental care (IRR 0.65, 95% CI 0.42-0.99), and moderate (IRR 1.38, 95% CI 1.04-1.83) or high (IRR 2.09, 95% CI 1.43-3.04) exposure to cigarette smoking were significantly associated with increased root DFT scores in the adjusted model 1. Individuals with intermediate (IRR 1.31, 95% CI 1.00-1.75) or high (IRR 1.57, 95% CI 1.06-2.31) educational status were more likely to have root caries. After adding gingivitis, the number of retained teeth, the number of teeth with recession, and coronal DMFT scores to the analysis, the risk estimates changed accordingly (adjusted model 2). The likelihood of root caries was statistically significantly higher for higher coronal DMFT scores (IRR 1.11, 95% CI 1.07-1.14) and a larger number of teeth with recession (IRR 1.18, 95% CI 1.15-1.22). The probability of root caries decreased with a higher tooth brushing frequency (IRR 0.75, 95% CI 0.59-0.96) and a larger number of retained teeth (IRR 0.92, 95% CI 0.89-0.95). A high educational status increased the likelihood of root caries by 74% (IRR 1.74, 95% CI 1.11-2.72).

Discussion

The present study was conducted to assess the association between educational status and coronal and root caries experience in adults and the elderly from Porto Alegre, South Brazil.

We found that individuals with a high educational status were more likely to have root caries and less likely to have coronal caries after adjusting for covariates. To the best of the authors' knowledge, this is the first population-based study to show that although educational status was a notable risk indicator for both coronal and root caries in older individuals, these conditions were associated with distinct social gradients.

Dental caries is increasingly regarded as closely following a social gradient (13). Recently, a systematic review assessed the association between socioeconomic indicators and coronal caries in adults aged 19-60 years by analyzing 41 cross-sectional, prospective cohort, and ecological studies (2). Of these studies, 21 employed multivariate analyses, whereas the remaining studies did not adjust for confounding variables. The systematic review revealed a gradient with poorer socioeconomic conditions being associated with greater caries severity. Furthermore, a cross-sectional study of Greek adults and elderly (aged 35-44 and 65-74 years, respectively) showed that those with >12 years of education were less likely to have coronal caries after controlling socio-demographic risk variables (5). Consistent with these findings, the present study found a significant association between a high educational status and higher coronal DMFT scores by using a multivariate model adjusted for well-known socio-demographic, behavioral, and clinical factors for coronal caries. The effect of educational status on coronal caries may be explained by increasing evidences associating poor socioeconomic conditions with poor attitudes toward oral health, such as a high consumption of cariogenic carbohydrates (14) and a low perceived need for and utilization of dental services (15).

In our study, a high educational status was significantly associated with higher root DFT scores in adults and the elderly, consistent with a previous study where Thai individuals aged 60-74 years with more than 4 years of education were 139% more likely to have root caries after adjusting for sex, age, coronal DMFT scores, the number of retained teeth, and the number of surfaces with recession (3). Other studies found either no relationship or negative associations between educational status and root caries in older individuals after adjusting for basic socio-demographic characteristics (4, 5).

After adding the number of retained teeth, number of teeth with recession, and coronal DMFT scores to our risk model, the likelihood of root caries increased from 57% to 74% in individuals with a high educational status, while the association between an intermediate educational status and root caries was no longer observed. Of note, gingival recession has been shown to be significantly associated with educational status and root caries. A recent report used the same sample as our study (1,023 South Brazilian individuals aged ≥35 years) to determine the risk indicators for gingival recession, and showed that a high educational status was significantly associated with a higher likelihood of gingival recession of ≥5 mm when considering only buccal sites (7). With regard to the relationship between gingival recession and root caries, our results observed that a larger number of teeth with recession increased the probability of root caries by 18%, which is in agreement with previous cross-sectional study in the elderly from Sri Lanka (16). It is thus plausible that individuals with a high educational status are more likely to have gingival recession and consequently a higher chance of root caries.

The results of our multivariate analyses cannot comprehensively explain the social gradient associated with coronal and root caries experience. We used a cross-sectional design for the present study; hence, a cause-and-effect relationship could not be established. However, this type of study provides useful data for longitudinal investigations.

In conclusion, educational status was a risk indicator for both coronal and root caries in the adult and elderly population of Porto Alegre, South Brazil. Clear social gradients associated with coronal and root caries were observed, but with different directionalities. The likelihood of coronal caries decreased with an increase in educational status. Conversely, individuals with a high educational status should be considered at high risk for root caries. Preventive strategies for root caries on the high educational status groups are required and may targeted gingival recession.

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Tables

Table 1. Study sample distribution and coronal and root caries experience according to socio-demographic and behavioral characteristics.

	n (%)	Coronal caries		Root caries	
		DMFT (95% CI)	*P*[a]	DFT (95% CI)	*P*[a]
Sex					
Male	398 (38.91)	17.86 (17.34-18.38)	ref.	1.37 (1.10-1.64)	ref.
Female	625 (61.09)	19.46 (18.74-20.18)	0.002	0.95 (0.75-1.16)	0.005
Age, years					
35-44	279 (27.27)	15.48 (14.59-16.36)	ref.	0.57 (0.35-0.79)	ref.
45-59	479 (46.82)	20.09 (19.54-20.63)	<0.001	1.40 (1.06-1.75)	0.001
≥60	265 (25.90)	21.78 (20.79-22.77)	<0.001	1.66 (1.26-2.06)	<0.001
Educational status					
Low	583 (56.99)	19.38 (18.69-20.07)	ref.	1.09 (0.91-1.27)	ref.
Intermediate	328 (32.06)	18.60 (17.83-19.37)	0.11	1.09 (0.90-1.28)	0.97
High	112 (10.95)	16.68 (15.30-18.05)	0.006	1.46 (0.43-2.50)	0.43
Tooth brushing frequency					
≤1 time/day	118 (11.53)	20.32 (18.73-21.92)	ref.	1.91 (1.20-2.62)	ref.
≥2 times/day	905 (88.47)	18.49 (17.91-19.08)	0.06	1.03 (0.88-1.19)	0.01
Proximal tooth cleaning frequency					
<1 time/day	533 (52.10)	19.36 (19.01-19.71)	ref.	1.22 (1.06-1.38)	ref.
≥1 time/day	490 (47.90)	18.02 (17.28-18.76)	0.001	1.07 (0.79-1.35)	0.17
Dental care frequency					
None or irregular	788 (77.03)	19.22 (18.60-19.83)	ref.	1.27 (0.98-1.57)	ref.
Regular	235 (22.97)	17.21 (15.57-18.85)	0.05	0.75 (0.55-0.95)	0.02
Exposure to cigarette smoking					
Never-smoker	463 (45.26)	18.63 (17.89-19.36)	ref.	0.80 (0.62-0.99)	ref.
Moderate smoker	299 (29.23)	17.85 (16.63-19.08)	0.31	1.21 (0.81-1.61)	0.01
Heavy smoker	261 (25.51)	20.20 (19.41-20.99)	0.005	1.77 (1.33-2.20)	0.002
Total	1,023 (100.00)	18.73 (18.29-19.17)		1.15 (0.95-1.34)	

95% CI, 95% confidence interval.
[a]Wald test.

Table 2. Association between coronal caries experience and explanatory variables (unadjusted and adjusted negative binomial regression analysis).

	Unadjusted model		Adjusted model[a]	
	IRR (95% CI)	*P*	IRR (95% CI)	*P*
Sex				
Male	1.00		1.00	
Female	1.08 (1.03-1.14)	0.002	1.09 (1.04-1.14)	0.001
Age, years[b]				
35-44	1.00		1.00	
45-59	1.29 (1.20-1.39)	<0.001	1.29 (1.19-1.40)	<0.001
≥60	1.40 (1.31-1.50)	<0.001	1.39 (1.29-1.49)	<0.001
Educational status[b]				
Low	1.00		1.00	
Intermediate	0.95 (0.91-1.01)	0.11	1.00 (0.95-1.05)	0.92
High	0.86 (0.77-0.95)	0.008	0.88 (0.78-0.99)	0.04
Tooth brushing frequency				
≤1 time/day	1.00			
≥2 times/day	0.91 (0.82-1.00)	0.05		
Proximal tooth cleaning frequency				
<1 time/day	1.00		1.00	
≥1 time/day	0.93 (0.89-0.96)	0.002	0.94 (0.91-0.97)	0.003
Dental care frequency				
None or irregular	1.00			
Regular	0.89 (0.79-1.00)	0.05		
Exposure to cigarette smoking				
Never-smoker	1.00			
Moderate smoker	0.95 (0.87-1.04)	0.32		
Heavy smoker	1.08 (1.02-1.14)	0.005		
Gingivitis				
≤20	1.00			
>20 to <60	1.00 (0.94-1.05)	0.93		
≥60	1.10 (1.03-1.17)	0.005		

IRR, incidence rate ratio; 95% CI, 95% confidence interval.

[a]No difference between adjusted model 1 (socio-demographic and behavioral variables) and adjusted model 2 (socio-demographic and behavioral variables, and gingivitis) was found.

[b]Variables maintained in the final model independently of the *P*-value.

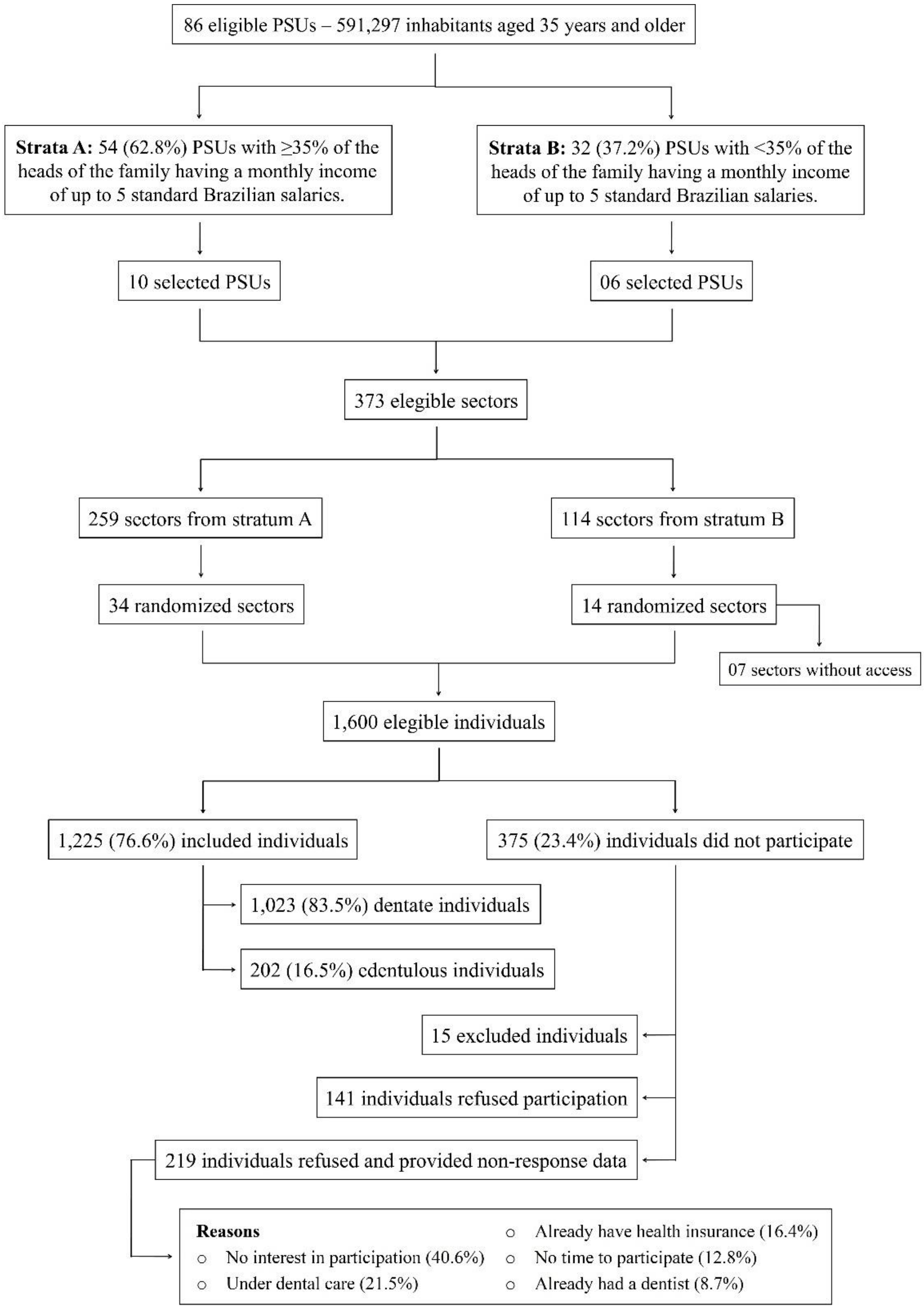
Table 3. Association between root caries experience and explanatory variables (unadjusted and adjusted negative binomial regression analysis).

	Unadjusted model		Adjusted model 1[a]		Adjusted model 2[b]	
	IRR (95% CI)	*P*	IRR (95% CI)	*P*	IRR (95% CI)	*P*
Sex						
Male	1.00					
Female	0.69 (0.55-0.87)	0.005				
Age, years[c]						
35-44	1.00		1.00		1.00	
45-59	2.45 (1.48--4.07)	0.002	2.21 (1.45-3.38)	0.001	1.04 (0.70-1.53)	0.81
≥60	2.90 (1.95-4.32)	<0.001	2.81 (2.13-3.70)	<0.001	1.10 (0.73-1.65)	0.60
Educational status[c]						
Low	1.00		1.00		1.00	
Intermediate	0.99 (0.78-1.26)	0.97	1.31 (1.00-1.75)	0.04	1.10 (0.88-1.37)	0.35
High	1.33 (0.68-2.62)	0.36	1.57 (1.06-2.31)	0.02	1.74 (1.11-2.72)	0.01
Tooth brushing frequency						
≤1 time/day	1.00		1.00		1.00	
≥2 times/day	0.54 (0.38-0.76)	0.002	0.68 (0.48-0.95)	0.02	0.75 (0.59-0.96)	0.02
Proximal tooth cleaning frequency						
<1 time/day	1.00					
≥1 time/day	0.87 (0.71-1.08)	0.20				
Dental care frequency						
None or irregular	1.00		1.00			
Regular	0.59 (0.38-0.90)	0.02	0.65 (0.42-0.99)	0.04		
Exposure to cigarette smoking						
Never-smoker	1.00		1.00			
Moderate smoker	1.50 (1.16-1.93)	0.004	1.38 (1.04-1.83)	0.02		
Heavy smoker	2.18 (1.47-3.25)	0.001	2.09 (1.43-3.04)	0.001		
Gingivitis						
≤20	1.00					
>20 to <60	0.95 (0.62-1.46)	0.83				
≥60	0.92 (0.54-1.56)	0.75				
Coronal DMFT scores	1.09 (1.07-1.12)	<0.001			1.11 (1.07-1.14)	<0.001
No. of retained teeth	0.96 (0.94-0.97)	<0.001			0.92 (0.89-0.95)	<0.001
No. of teeth with recession	1.06 (1.04-1.08)	<0.001			1.18 (1.15-1.22)	<0.001

IRR, incidence rate ratio; 95% CI, 95% confidence interval.
[a]Estimates adjusted for socio-demographic and behavioral variables.
[b]Estimates adjusted for socio-demographic, behavioral, and clinical variables.
[c]Variables maintained in the final model independently of the *P*-value.

Figure legends

Figure 1. Flowchart of sampling strategy and response rate (PSU = primary sampling unit).


86 eligible PSUs – 591,297 inhabitants aged 35 years and older
Strata A: 54 (62.8%) PSUs with ≥35% of the heads of the family having a monthly income of up to 5 standard Brazilian salaries.
Strata B: 32 (37.2%) PSUs with <35% of the heads of the family having a monthly income of up to 5 standard Brazilian salaries.
10 selected PSUs
06 selected PSUs
373 elegible sectors
259 sectors from stratum A
114 sectors from stratum B
34 randomized sectors
14 randomized sectors
07 sectors without access
1,600 elegible individuals
1,225 (76.6%) included individuals
375 (23.4%) individuals did not participate
1,023 (83.5%) dentate individuals
202 (16.5%) edentulous individuals
15 excluded individuals
141 individuals refused participation
219 individuals refused and provided non-response data
Reasons
No interest in participation (40.6%)
Under dental care (21.5%)
Already have health insurance (16.4%)
No time to participate (12.8%)
Already had a dentist (8.7%)

Paper III

Coronal and root caries activity among adults and the elderly from South Brazil: prevalence estimates and assessment of risk indicators

Coronal and root caries activity among adults and the elderly from South Brazil: prevalence estimates and assessment of risk indicators

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Short title
Coronal and root caries activity in adults and the elderly

Key words
Dental caries, root caries, epidemiology, prevalence, risk factors, adult

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Declaration of interests

The authors declare that they have no proprietary, financial, professional, or other personal interest of any kind in any product, service, or company that could influence the position presented in or the review of the manuscript "**Coronal and root caries activity among adults and the elderly from South Brazil: prevalence estimates and assessment of risk indicators**".

Abstract

This cross-sectional study aimed to assess the prevalence estimates and risk indicators for coronal and root caries activity among adults and the elderly from South Brazil. A multistage sampling strategy was used to draw a representative sample of 1,023 subjects aged ≥35 years. Questionnaires recorded data on socio-demographic characteristics, oral hygiene habits, dental care, and smoking. Oral examination assessed gingival bleeding, gingival recession, and coronal and root caries activity. Survey Poisson regression models were used for data analysis (prevalence ratio/95% confidence interval). The prevalence of coronal and root caries activity was 34.26% (95% CI 27.13-41.38) and 14.73% (95% CI 11.16-18.30). Probability of coronal caries activity decreased with age ≥60 years (PR 0.48, 95% CI 0.32-0.72), higher tooth brushing frequency (PR 0.57, 95% CI 0.43-0.76), higher proximal tooth cleaning frequency (PR 0.83, 95% CI 0.71-0.98), regular dental care (PR 0.35, 95% CI 0.25-0.50), and larger number of retained teeth (PR 0.98, 95% CI 0.97-0.99), and increased with ≥60% of bleeding sites (PR 1.71, 95% CI 1.19-2.43). Probability of root caries activity decreased with larger number of retained teeth (PR 0.88, 95% CI 0.86-0.90), and increased with moderate-high educational status (PR 1.32, 95% CI 1.01-1.71) and larger number of teeth with recession (PR 1.08, 95% CI 1.05-1.12). Coronal caries activity increased the likelihood of root caries activity by 394% (PR 4.94, 95% CI 3.23-7.55). In conclusion, caries activity was highly prevalent in this study population. Those with coronal caries activity should be considered at high risk for root caries activity.

Introduction

Dental caries is a complex disease that recurs throughout life and may cause irreversible damage to the dental hard tissues [Featherstone, 2008]. Caries diagnosis includes the detection of caries lesions, and cross-sectional and prospective cohort studies were conducted to better understand the lesion progression [Luan et al., 1989; Manji et al., 1989]. Luan et al. [1989] indicated pulpally involved lesions and root surface lesions as the predominant components of the DFT index in Chinese adults aged ≥50 years with poor oral hygiene. Manji et al. [1989] found that pulpally involved lesions, missing teeth, and root surface lesions predominated in Kenyan adults aged 55-65 years compared to younger age groups. Both studies concluded that caries activity continually progressed throughout life. To avoid the destruction wrought by dental caries on tooth tissues, it is crucial to predict the lesion progression and determine the appropriate treatment.

Current studies have shown the feasibility of detecting lesion activity reliably and accurately [Braga et al., 2009; Ekstrand et al., 2007; Guedes et al., 2014; Nyvad et al., 1999, 2003], yet caries activity is rarely evaluated in epidemiological surveys. Very few prevalence [Carvalho et al., 2014; Rihs et al., 2007] and incidence [Carvalho et al., 2009] studies assessed caries activity in preschool children, and there are no population-based studies in adults and the elderly. With people living longer [Paim et al., 2011], retaining their teeth for longer [Peres et al., 2013], and experiencing greater exposure of root surfaces [Rios et al., 2014], reports on the coronal and root caries activity in older people have become essential for the establishment of measures for controlling caries.

Therefore, the aim of the present study was to assess the prevalence estimates and risk indicators for coronal and root caries activity in a representative sample of adults and the elderly from Porto Alegre, South Brazil.

Subjects and Methods

This cross-sectional study was part of the Caries-Perio Collaboration Survey, which included 1,225 subjects aged ≥35 years from Porto Alegre, South Brazil. The fieldwork was conducted from June 2011 to June 2012.

Sampling strategy and sample size calculation

This study used a multistage stratified random sampling strategy (Figure 1). In the first stage, the city was divided into 86 neighbourhoods (primary sampling units [PSUs]). The PSUs were then divided into high- versus low-income strata. PSUs were randomly selected in proportion to the number of PSUs in each stratum. In the second stage, random sectors (map areas comprising approximately 300 households) were selected in proportion to the total number of sectors in each PSU; 48 of the 373 elegible sectors were selected. In the third and final stage, consecutive households were selected (beginning at the sector starting point and continuing until the sector sample size was reached). The number of subjects to be selected within each sector was estimated based on the proportional distribution of the sample size according to the number of subjects aged ≥35 years who were living in each sector. All household members aged ≥35 years were eligible for the study. Subjects with mental or systemic health conditions that precluded the realization of interviews or clinical examinations were excluded. Non-residential establishments such as nursing homes and commercial establishments were not approached. Detailed information about the methodology used has been already described [Costa et al., 2014].

This was a multi-disciplinary study measuring a variety of oral outcomes; therefore, the sample size calculation used a 50% prevalence (worst-case scenario) for any oral condition assessed. A multistage sampling strategy was employed but was estimated to yield approximately 50% inefficiency. A standard formula for prevalence estimation was applied adjusting the sample size for this design effect. Assuming a ±4% precision level and a 95% confidence interval (CI), a sample size of 940 subjects was estimated.

Data collection

Study participants were interviewed and underwent an oral examination in their own homes, performed by three trained and calibrated researchers (FSR, MSM and RSAC). A structured questionnaire including questions regarding socio-demographic characteristics, oral hygiene habits, dental care, and smoking was used. A test-retest approach was performed to assess the reliability of the questionnaire (unweighted Cohen's kappa varied from 0.91 to 0.99).

The clinical examination was conducted in the supine position. Field equipment included portable lights, an air compressor, plane mouth mirrors, and periodontal probes. Two examiners (FSR and RSAC) performed the gingival examination. Gingivitis was assessed using the gingival bleeding index [Ainamo and Bay, 1975]. Gingival recession was defined as the distance from the cement-enamel junction to the free gingival margin. After teeth cleaning and drying, a single examiner (MSM) assessed caries activity. Coronal lesions were classified as follows: (1) active non-cavitated, opaque and dull-white surface with surface continuity; (2) inactive non-cavitated, shiny surface with surface continuity; (3) active cavitated, localized surface destruction with opaque and dull-white enamel, and soft dentin; and (4) inactive cavitated, localized surface destruction with shiny enamel and hard dentin. Root lesions were graded as follows: (1) active non-cavitated, opaque and dull-yellow surface with surface continuity; (2) inactive non-cavitated, shiny surface with surface continuity; (3) active cavitated, localized surface destruction with opaque and dull-yellow cementum, and soft dentin; and (4) inactive cavitated, localized surface destruction with shiny cementum and hard dentin. Intra-examiner reliability for the caries assessment was conducted by repeated examinations in 5% of the sample within a 1-week interval. The lowest unweighted Cohen's kappa was 0.77. Similarly, intra-examiner reliability for the gingival recession assessment revealed weighted (±1 mm) Cohen's kappa values of 0.98 and 0.99, and an inter-examiner value of 0.91.

Non-response analysis

In statistical analyses, non-response was accounted for by using the inverse probability weighting strategy [Hernán et al., 2004]. A non-response weight variable considering eligible and actual participants as well as the distributions of age, sex, and educational status was generated for each sector.

A total of 375 (23.43%) subjects did not participate in the Caries-Perio Collaboration Survey. Reasons for non-participation are described in Figure 1. Some questions in the questionnaire were answered by 219 (58.40%) non-respondents; these data were compared with data from the subjects included in the final sample. The non-respondents were slightly older than the respondents (mean age 55.50 ± 11.80 *vs.* 52.60 ± 11.80 years, $P = 0.001$), and the percentage of subjects with a high educational status was significantly higher in the non-respondent group than in the respondent group. No significant differences regarding the proportion of men versus women and the self-reported mean number of missing teeth were found between the two groups.

Data analysis

The present data analysis included all dentate subjects ($n = 1{,}023$) from the Caries-Perio Collaboration Survey. The prevalence of coronal caries was defined according to (1) activity, the percentage of subjects with at least one active lesion; and (2) extent, the percentage of subjects with at least one decayed, missing, or filled surface. The prevalence of root caries was defined according to (1) activity, the percentage of subjects with at least one active lesion; and (2) extent, the percentage of subjects with at least one decayed or filled surface.

Participant age was categorized as 35-59 or ≥60 years. Educational status was based on the number of years of education and was categorized as low (0-8 years), intermediate (9-11 years), or high (>11 years). Tooth brushing and proximal tooth cleaning frequency were dichotomized as ≤1 time/day versus ≥2 times/day and <1 time/day versus ≥1 time/day, respectively. Dental care in the last 3 years was dichotomized as irregular (no dental visit or visits only for emergencies) versus regular (visits for prevention with a frequency of ≥2 times/year). Former and current smokers were considered to have had exposure to cigarette smoking. The number of packs of cigarettes consumed in a lifetime (pack-years) was calculated by multiplying the number of cigarettes consumed per day by the years of habit, divided by 20. Subjects were classified as never-smokers (0 pack-years), moderate smokers (<20 pack-years), or heavy smokers (≥20 pack-years). Gingivitis was categorized according to the percentage of bleeding sites on probing (≤20%, 21% to 59%, and ≥60%). The number of retained teeth and number of teeth with recession of ≥1 mm were modeled as continuous variables.

Data analysis was performed using STATA software (Stata 11.1 for Windows, Stata Corporation, College Station, Texas, USA). A sampling weight variable was computed using census information provided by the Brazilian Institute of Geography and Statistics. Complex survey commands were applied to account for cluster correlations expected for the multistage sampling strategy used in this study. Pair-wise comparisons of crude estimates were performed using the Wald test. The significance level was set at 5%. Survey Poisson regression models were applied to assess the association between caries activity and explanatory variables. Estimates were adjusted for socio-demographic and behavioral variables (adjusted model 1). In the adjusted model 2, we additionally adjusted for clinical variables. A preliminary analysis using univariate models was performed, and variables showing associations with a $P<0.25$ were added to the multivariate models. Maintenance of variables in the final model was determined by a combination of a $P<0.05$ and analyses of confounders and interactions [Hosmer and Stanley, 2000]. Prevalence ratios (PR) and 95% CIs were estimated and reported.

Ethical considerations

The study protocol was approved by the Federal University of Rio Grande do Sul Research Ethics Committee (19794/11). Signed informed consent was obtained from all study participants.

Results

A total of 1,600 subjects were eligible for the Caries-Perio Collaboration Survey (Figure 1). Of them, 375 (23.43%) did not participate in the survey (non-respondents), resulting in a final sample of 1,225 (76.56%) subjects. The present sub-study comprised all dentate subjects (n = 1,023), among which 398 (38.91%) were men and 625 (61.09%) were women aged 35-95 years.

The mean number of coronal surfaces with non-cavitated and cavitated active lesion was 1.72 (standard error [SE] 0.19) and 0.75 (SE 0.18) in the age groups of 35-59 and ≥60 years, respectively (P = 0.001, Wald test). The mean number of root surfaces with cavitated active lesion was 0.29 (SE 1.09) in the younger group and 0.46 (SE 0.12) in the older group (P = 0.21, Wald test).

The overall prevalence of coronal and root caries was 100% and 44.30% (95% CI 40.51-48.10), respectively. As shown in Table 1, the prevalence of coronal and root caries activity was 34.26% (95% CI 27.13-41.38) and 14.73% (95% CI 11.16-18.30), respectively. Significant differences in the coronal caries activity were observed according to age, educational status, tooth brushing frequency, proximal tooth cleaning frequency, and dental care frequency. Root caries activity significantly differed according to educational status, tooth brushing frequency, proximal tooth cleaning frequency, dental care frequency, and exposure to cigarette smoking.

As shown in Table 2, age ≥60 years (PR 0.54, 95% CI 0.37-0.80), a higher tooth brushing frequency (PR 0.56, 95% CI 0.43-0.74), a higher proximal tooth cleaning frequency (PR 0.78, 95% CI 0.65-0.93), and regular dental care (PR 0.32, 95% CI 0.22-0.46) were significantly associated with a lower prevalence of coronal caries activity in the first multivariate model. After adding gingivitis and the number of retained teeth to the analysis, the risk estimates increased slightly in all of these variables, except age (adjusted model 2). The probability of coronal caries activity decreased with age ≥60 years (PR 0.48, 95% CI 0.32-0.72), a higher tooth brushing frequency (PR 0.57, 95% CI 0.43-0.76), a higher proximal tooth cleaning frequency (PR 0.83, 95% CI 0.71-0.98), regular dental care (PR 0.35, 95% CI

0.25-0.50), and a larger number of retained teeth (PR 0.98, 95% CI 0.97-0.99), and increased with ≥60% of bleeding sites (PR 1.71, 95% CI 1.19-2.43).

In the first multivariable model, root caries activity was significantly associated with a higher proximal tooth cleaning frequency (PR 0.56, 95% CI 0.36-0.86), regular dental care (PR 0.40, 95% CI 0.18-0.90), and greater exposure to cigarette smoking (PR 2.18, 95% CI 1.27-3.74, Table 3). After adding gingivitis, coronal caries activity, the number of retained teeth, and the number of teeth with recession to the analysis, the risk estimates changed accordingly (adjusted model 2). Proximal tooth cleaning frequency, dental care, and exposure to cigarette smoking were no longer associated with root caries activity. In addition, the probability of root caries activity decreased with a larger number of retained teeth (PR 0.88, 95% CI 0.86-0.90), and increased with moderate-high educational status (PR 1.32, 95%CI 1.01-1.71) and a larger number of teeth with recession (PR 1.08, 95% CI 1.05-1.12). Coronal caries activity increased the likelihood of root caries activity by 394% (PR 4.94, 95% CI 3.23-7.55).

Discussion

This study was conducted to assess the prevalence estimates and risk indicators for coronal and root caries activity in a representative sample of adults and the elderly from Porto Alegre, South Brazil. The prevalence of coronal caries activity in the study population was approximately 2.5 times higher than the prevalence of root caries activity. The most relevant finding was that coronal caries activity significantly increased the likelihood of root caries activity. To the best of our knowledge, this is the first population-based study assessing the prevalence estimates and risk indicators for caries activity in adults aged ≥35 years.

Increasing evidence suggests that dental caries could be classified according to its activity [Braga et al., 2009; Ekstrand et al., 2007; Guedes et al., 2014; Nyvad et al., 1999, 2003]. This is an important concept that directly affects caries management. The present study showed coronal and root caries prevalences of 100% and 44.30%, respectively, using well-known caries experience criteria (modified DMFT index). The use of these epidemiological data to predict treatment should be done with caution because the data comprised non-cavitated inactive lesions. When only non-cavitated and cavitated active lesions were included in the prevalence estimates, the prevalence of coronal and root caries decreased to 34.26% and 14.73%, respectively. However, it is important to emphasize that at least one-third of the study population showed caries activity. Thus, it may be concluded that a large number of adults and the elderly from Porto Alegre, Brazil require intervention (non-operative or operative treatment) to arrest disease progression and improve oral health.

Multivariate analyses were applied to identify risk indicators for coronal caries activity in this adult and elderly population. While sex, educational status, and exposure to cigarette smoking were not associated with coronal caries activity, poor oral hygiene habits and irregular dental care emerged as significant risk indicators for the outcome in both adjusted models. Gingivitis (≥60% of bleeding sites) also increased the likelihood of coronal caries activity. These findings highlight the significant impact of behavioral factors on the development and progression of coronal caries.

Exploratory analysis of our data indicated that increased age was significantly associated with higher coronal DMFT scores (unpublished data). This finding may reflect the difficulty of the elderly in mechanically removing plaque due to their diminished manual dexterity, impaired vision, and other debilitating conditions [Akar and Ergül, 2008; Simons et al., 2001]. However, the same relationship was not found between age and coronal caries activity. The present study showed a gradual decrease in the mean number of coronal active lesions according to increased age, and the adjusted models indicated a lower likelihood of coronal caries activity in the elderly. These results may be explained, in part, by the larger proportion of biofilm stagnation areas that were already filled in adults and the elderly. Furthermore, cumulative de- and re-mineralization of the coronal surfaces occurs throughout life, which replaces the lost soluble minerals with minerals of higher acid resistance [Maltz et al., 2006; Richards et al., 1977]. Thus, it is plausible to find a lower number of coronal active lesions in subjects aged ≥60 years.

Our previous analyses observed that the probability of root caries experience was affected primarily by the number of retained teeth, gingival recession, and coronal caries experience (unpublished data). Therefore, the present study carefully investigated the association between root caries activity and explanatory variables using two multivariable models. Although behavioral variables were significantly associated with the root caries activity in the first adjusted model, this relationship was not found after adding the number of retained teeth, number of teeth with recession, and coronal caries activity in the final adjusted model. Such variability between both multivariable models may have occurred because the behavioral variables were highly correlated with clinical characteristics, which may have directly influenced the associations.

The present study showed that coronal caries activity had the strongest association with the root caries activity of all risk indicators. Studies investigating the progression of caries lesions at various life stages observed that middle-aged people generally have a larger number of root caries lesions compared to younger subjects [Luan et al., 1989; Manji et al., 1989]. This finding may reflect the greater exposure of root surfaces to the oral environment in adults and the elderly [Rios et al., 2014; Susin et al., 2004]. Notably, increased age and gingival recession have been considered biological factors required for the onset of root caries [Katz, 1980; Locker, 1996]. This may suggest that root caries can be prevented by controlling coronal caries activity at a younger age before root surfaces are exposed. Comprehensive measures including oral hygiene, widespread use of fluoride, and dietary control should be included in a multifaceted strategy for coronal caries control [Longbottom et al., 2009].

In conclusion, caries activity was highly prevalent in adults and the elderly from South Brazil. Age, oral hygiene habits, dental care, gingivitis, and the number of retained teeth were risk indicators for coronal caries activity. Root caries activity was significantly associated with educational status, the number of retained teeth, and the number of teeth with gingival recession. Furthermore, coronal caries activity greatly increased the likelihood of root caries activity and should be targeted in preventive strategies during early life prior to exposure of root surfaces.

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Legends

Table 1. Study sample distribution and coronal and root caries activity according to socio-demographic and behavioral characteristics.

Table 2. Association between coronal caries activity and explanatory variables (unadjusted and adjusted Poisson regression analysis).

Table 3. Association between root caries activity and explanatory variables (unadjusted and adjusted Poisson regression analysis).

Figure 1. Flowchart of sampling strategy and response rate (PSU = primary sampling unit).

Table 1

	n (%)	Coronal caries activity		Root caries activity	
		Prevalence (95% CI)	P^*	Prevalence (95% CI)	P^*
Sex					
Male	398 (38.91)	36.70 (24.50-48.89)	ref.	17.57 (9.61-25.54)	ref.
Female	625 (61.09)	32.18 (25.89-38.48)	0.46	12.31 (9.01-15.62)	0.25
Age, years					
35-59	758 (74.10)	37.99 (29.38-46.61)	ref.	14.66 (9.94-19.38)	ref.
≥60	265 (25.90)	22.05 (14.12-29.98)	0.01	14.96 (7.19-22.74)	0.94
Educational status					
Low	661 (64.61)	39.53 (30.49-48.57)	ref.	16.48 (11.99-20.97)	ref.
Intermediate-high	362 (35.39)	26.09 (19.42-32.77)	0.01	12.02 (8.16-15.88)	0.04
Tooth brushing frequency					
≤1 time/day	118 (11.53)	63.92 (42.55-85.29)	ref.	33.90 (9.75-58.06)	ref.
≥2 times/day	905 (88.47)	29.93 (22.76-37.09)	0.005	11.93 (9.10-14.76)	0.08
Proximal tooth cleaning frequency					
<1 time/day	533 (52.10)	41.26 (33.79-48.74)	ref.	19.17 (13.03-25.31)	ref.
≥1 time/day	490 (47.90)	26.44 (18.82-34.07)	<0.001	9.78 (6.88-12.67)	0.01
Dental care frequency					
None or irregular	788 (77.03)	41.58 (33.43-49.73)	ref.	17.56 (12.40-22.73)	ref.
Regular	235 (22.97)	11.57 (6.31-16.84)	<0.001	5.95 (1.80-10.11)	0.007
Exposure to cigarette smoking					
Never-smoker	463 (45.26)	31.00 (21.40-40.60)	ref.	10.82 (5.39-16.26)	ref.
Moderate smoker	299 (29.23)	34.89 (25.95-43.82)	0.42	13.57 (9.06-18.08)	0.26
Heavy smoker	261 (25.51)	40.12 (31.12-49.12)	0.10	24.54 (20.15-28.93)	0.003
Total	1,023 (100.00)	34.26 (27.13-41.38)		14.73 (11.16-18.30)	

95% CI, 95% confidence interval.
*Wald test.

Table 2

	Unadjusted model		Adjusted model 1[b]		Adjusted model 2[c]	
	PR (95% CI)	*P*	PR (95% CI)	*P*	PR (95% CI)	*P*
Sex						
Male	1.00					
Female	0.87 (0.61-1.24)	0.43				
Age, years[a]						
35-59	1.00		1.00		1.00	
≥60	0.58 (0.37-0.88)	0.01	0.54 (0.37-0.80)	0.006	0.48 (0.32-0.72)	0.002
Educational status						
Low	1.00					
Intermediate-high	0.66 (0.49-0.87)	0.008				
Tooth brushing frequency						
≤1 time/day	1.00		1.00		1.00	
≥2 times/day	0.46 (0.31-0.69)	0.001	0.56 (0.43-0.74)	0.001	0.57 (0.43-0.76)	0.001
Proximal tooth cleaning frequency						
<1 time/day	1.00		1.00		1.00	
≥1 time/day	0.64 (0.52-0.78)	<0.001	0.78 (0.65-0.93)	0.01	0.83 (0.71-0.98)	0.03
Dental care frequency						
None or irregular	1.00		1.00		1.00	
Regular	0.27 (0.18-0.42)	<0.001	0.32 (0.22-0.46)	<0.001	0.35 (0.25-0.50)	<0.001
Exposure to cigarette smoking						
Never-smoker	1.00					
Moderate smoker	1.12 (0.82-1.53)	0.42				
Heavy smoker	1.29 (0.93-1.79)	0.11				
Gingivitis (bleeding sites), %						
≤20	1.00				1.00	
>20 to <60	1.35 (1.02-1.80)	0.03			1.25 (0.97-1.61)	0.07
≥60	2.15 (1.46-3.17)	0.001			1.71 (1.19-2.43)	0.006
No. of retained teeth	0.98 (0.96-0.99)	0.01			0.98 (0.97-0.99)	0.04

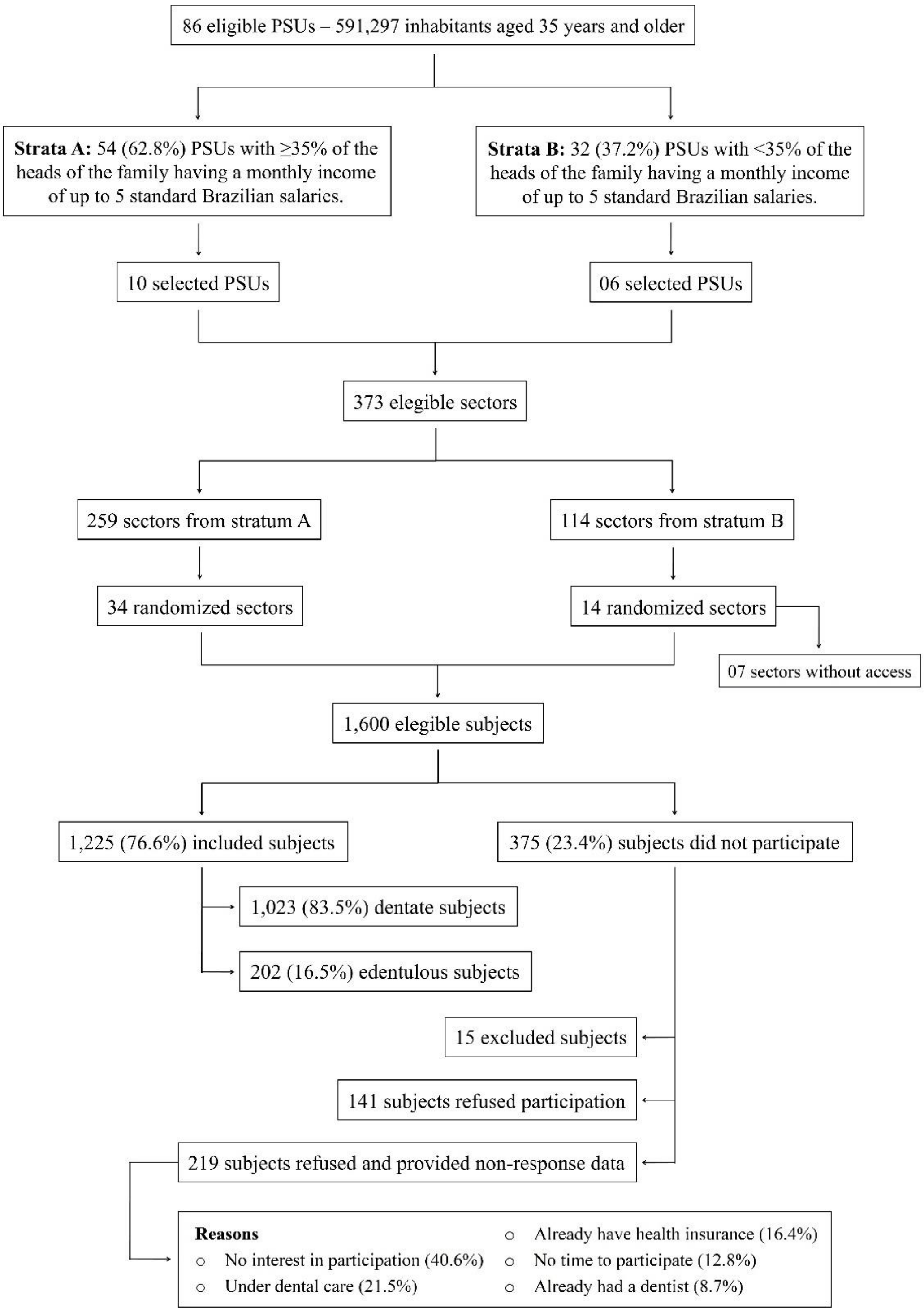
PR, prevalence ratio; 95% CI, 95% confidence interval.
[a]Variable maintained in the final model independently of the *P*-value;
[b]Estimates adjusted for socio-demographic and behavioral variables.
[c]Estimates adjusted for socio-demographic, behavioral, and clinical variables.

Table 3

	Unadjusted model		Adjusted model 1[b]		Adjusted model 2[c]	
	PR (95% CI)	*P*	PR (95% CI)	*P*	PR (95% CI)	*P*
Sex						
Male	1.00					
Female	0.70 (0.38-1.26)	0.21				
Age, years[a]						
35-59	1.00		1.00		1.00	
≥60	1.02 (0.51-2.02)	0.94	0.94 (0.47-1.84)	0.84	0.76 (0.51-1.15)	0.18
Educational status						
Low	1.00				1.00	
Intermediate-high	0.72 (0.53-1.00)	0.05			1.32 (1.01-1.71)	0.03
Tooth brushing frequency						
≤1 time/day	1.00					
≥2 times/day	0.35 (0.15-0.79)	0.01				
Proximal tooth cleaning frequency						
<1 time/day	1.00		1.00			
≥1 time/day	0.51 (0.32-0.80)	0.008	0.56 (0.36-0.86)	0.01		
Dental care frequency						
None or irregular	1.00		1.00			
Regular	0.33 (0.14-0.80)	0.01	0.40 (0.18-0.90)	0.03		
Exposure to cigarette smoking						
Never-smoker	1.00					
Moderate smoker	1.25 (0.80-1.95)	0.29	1.25 (0.82-1.92)	0.26		
Heavy smoker	2.26 (1.25-4.08)	0.01	2.18 (1.27-3.74)	0.008		
Gingivitis (bleeding sites), %						
≤20	1.00					
>20 to <60	1.06 (0.55-2.02)	0.83				
≥60	2.47 (1.18-5.15)	0.02				
Coronal caries activity						
Absent	1.00				1.00	
Present	5.78 (3.22-10.35)	<0.001			4.94 (3.23-7.55)	<0.001
No. of retained teeth	0.93 (0.91-0.94)	<0.001			0.88 (0.86-0.90)	<0.001
No. of teeth with recession	0.98 (0.95-1.00)	0.11			1.08 (1.05-1.12)	<0.001

PR, prevalence ratio; 95% CI, 95% confidence interval.
[a]Variable maintained in the final model independently of the *P*-value;
[b]Adjusted model 1 = estimates adjusted for sociodemographic and behavioral variables.
[c]Adjusted model 2 = estimates adjusted for sociodemographic, behavioral, and clinical variables.

Figure 1



86 eligible PSUs – 591,297 inhabitants aged 35 years and older
Strata A: 54 (62.8%) PSUs with ≥35% of the heads of the family having a monthly income of up to 5 standard Brazilian salaries.
Strata B: 32 (37.2%) PSUs with <35% of the heads of the family having a monthly income of up to 5 standard Brazilian salaries.
10 selected PSUs
06 selected PSUs
373 elegible sectors
259 sectors from stratum A
114 sectors from stratum B
34 randomized sectors
14 randomized sectors
07 sectors without access
1,600 elegible subjects
1,225 (76.6%) included subjects
375 (23.4%) subjects did not participate
1,023 (83.5%) dentate subjects
202 (16.5%) edentulous subjects
15 excluded subjects
141 subjects refused participation
219 subjects refused and provided non-response data
Reasons
No interest in participation (40.6%)
Under dental care (21.5%)
Already have health insurance (16.4%)
No time to participate (12.8%)
Already had a dentist (8.7%)

Paper IV

Overweight and obesity are not associated with coronal and root caries experience in adults and the elderly

Overweight and obesity are not associated with coronal and root caries experience in adults and the elderly

Running head: Overweight/obesity and caries experience in adults

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Abstract

Objective: The aim of this study was to assess the relationship of overweight and obesity with coronal and root caries experience among adults and the elderly from southern Brazil. *Methods:* A multistage sampling strategy was used to draw a representative sample of 1,023 individuals aged ≥35 years. Questionnaires recorded data on socio-demographic characteristics, oral hygiene habits, dental care, and smoking. Oral examination assessed gingival bleeding, gingival recession, and coronal and root caries. Anthropometric measures were collected to calculate the body mass index. Survey negative binomial regression models were used for data analysis (incidence rate ratio/95% confidence interval). *Results:* The prevalence of overweight and obesity was 39.80% (95% CI 35.18-44.41) and 31.33% (95% CI 26.50-36.16), respectively. The mean coronal DMFT and root DFT scores was 18.68 (95% CI 18.24-19.13) and 1.14 (95% CI 0.95-1.34), respectively. No significant differences in coronal and root caries experience were found among the weight status groups. After adjusting for confounding variables, weight status was not associated with coronal caries experience (overweight, IRR 0.98, 95% CI 0.94-1.03; obesity, IRR 0.98, 95% CI 0.92-1.04) and root caries experience (overweight, IRR 0.99, 95% CI 0.67-1.45; obesity, IRR 1.01, 95% CI 0.69-1.50). *Conclusions:* Our findings indicate that overweight and obese individuals should not be considered at high risk for both coronal and root caries.

Introduction

Overweight and obesity are defined as abnormal or excessive fat accumulation that represents a risk to general health (1). Indeed, excessive body weight is a well-known risk factor for many systemic diseases, such as diabetes (2), cancer (3), and cardiovascular disease (4). Current evidence suggests that overweight and obesity have become a public health problem in both developed and developing nations (5, 6). Available data from Brazil showed that 52.8% of the adults aged 35-44 years were affected by overweight and 15.6% by obesity (7). A slightly higher prevalence of overweight (56.2%) and obesity (17.9%) were observed among older people aged 65-74 years.

Unhealthy diet plays an important role in promoting overweight and obesity. A high-sugar diet has been associated with weight gain (8, 9) and is recognized as a key factor in the development of dental caries (10). Therefore, it has been suggested that overweight or obese individuals are at increased risk for dental caries because these conditions may share a common risk factor. However, a systematic review and meta-analysis exploring the relationship between obesity and dental caries in children showed inconclusive findings after evaluating the studies published between 1980 and 2010 (11). Other recent studies have also shown conflicting results (12-17). To date, this relationship has not been examined in the adult and elderly population.

Therefore, the aim of this study was to assess the relationship of overweight and obesity with coronal and root caries experience in a representative sample of adults and the elderly from Porto Alegre, southern Brazil.

Materials and methods

This cross-sectional study was part of the Caries-Perio Collaboration Survey, which included 1,225 individuals aged ≥35 years from Porto Alegre, southern Brazil. The fieldwork was conducted from June 2011 to June 2012. The study protocol was approved by the Federal

University of Rio Grande do Sul Research Ethics Committee (19794/11). Signed informed consent was obtained from all study participants.

Sample size calculation and sampling strategy

This was a multi-disciplinary study measuring a variety of oral outcomes; therefore, the sample size calculation used a 50% prevalence (worst-case scenario) for any oral condition assessed. A multistage sampling strategy was employed but was estimated to yield approximately 50% inefficiency. A standard formula for prevalence estimation was applied adjusting the sample size for this design effect. Assuming a ±4% precision level and a 95% confidence interval (CI), a sample size of 940 individuals was estimated. The minimum size of this sample to provide 80% statistical power and identify an odds ratio of 1.5 and/or a risk ratio of 1.2 was estimated to be 816 individuals (18). The calculation was based on the assumption that 50% of the unexposed population and 60% of the exposed population would have the outcome of interest, with an α equal to 0.05 and a β equal to 0.20.

This study used a multistage stratified random sampling strategy (Figure 1). In the first stage, the city was divided into 86 neighbourhoods (primary sampling units [PSUs]). The PSUs were then divided into high- versus low-income strata. PSUs were randomly selected in proportion to the number of PSUs in each stratum. In the second stage, random sectors (map areas comprising approximately 300 households) were selected in proportion to the total number of sectors in each PSU; 48 of the 373 elegible sectors were selected. In the third and final stage, consecutive households were selected (beginning at the sector starting point and continuing until the sector sample size was reached). The number of individuals to be selected within each sector was estimated based on the proportional distribution of the sample size according to the number of individuals aged ≥35 years who were living in each sector. All household members aged ≥35 years were eligible for the study. Individuals with mental or systemic health conditions that precluded the realization of interviews or clinical examinations were excluded. Non-residential establishments such as nursing homes and commercial establishments were not approached. Detailed information about the methodology used has been already described (19).

Data collection

Study participants were interviewed and underwent an oral examination in their own homes, performed by three trained and calibrated researchers (FSR, MSM and RSAC). A structured questionnaire comprising questions regarding socio-demographic characteristics, oral hygiene habits, dental care, and smoking was used. A test-retest approach was performed to assess the reliability of the questionnaire (unweighted Cohen's kappa varied from 0.91 to 0.99).

The clinical examination was conducted in the supine position. Field equipment included portable lights, an air compressor, plane mouth mirrors, and periodontal probes. Two examiners (FSR and RSAC) performed the gingival examination. Gingivitis was assessed using the gingival bleeding index (20). Gingival recession was defined as the distance from the cement-enamel junction to the free gingival margin. After teeth cleaning and drying, a single examiner (MSM) performed the caries examination and recorded whether the coronal and root surfaces were sound, decayed, missing, or filled. Non-cavitated (coronal caries, opaque and dull-white surface with surface continuity; root caries, opaque and dull-yellow surface with surface continuity) and cavitated caries lesions were also assessed for coronal and root surfaces (21). Anthropometric data were collected for the calculation of the body mass index (BMI, weight (kg)/height $(m)^2$). Weight was obtained using a 150 kg digital scale. Height was measured to the nearest full centimeter using an inelastic metric tape. The measurements were made by three researchers (MSM, FSR, and RSAC) with the participants wearing no shoes. Intra-examiner reliability for the caries assessment was conducted by repeated examinations in

5% of the sample within a 1-week interval. The lowest unweighted Cohen's kappa was 0.77. Similarly, intra-examiner reliability for the gingival assessment revealed weighted (±1 mm) Cohen's kappa values of 0.98 and 0.99, and an inter-examiner value of 0.91.

Non-response analysis

In statistical analyses, non-response was accounted for by using the inverse probability weighting strategy (22). A non-response weight variable considering eligible and actual participants as well as the distributions of age, sex, and educational status was generated for each sector.

A total of 375 (23.43%) individuals did not participate in the Caries-Perio Collaboration Survey. Reasons for non-participation are described in Figure 1. Some questions in the questionnaire were answered by 219 (58.40%) non-respondents; these data were compared with data from the individuals included in the final sample. The non-respondents were slightly older than the respondents (mean age 55.50 ± 11.80 *vs.* 52.60 ± 11.80 years, $P = 0.001$), and the percentage of individuals with a high educational status was significantly higher in the non-respondent group than in the respondent group. No significant differences regarding the proportion of men versus women and the self-reported mean number of missing teeth were found between the two groups.

Data analysis

The present sub-study did not include underweight individuals or those in which anthropometric measures were not obtained. Thus, the data analysis comprised a total of 1,002 dentate individuals. The primary outcomes were the mean coronal decayed, missing, and filled teeth (DMFT) score and the mean root decayed and filled teeth (DFT) score.

Weight status (BMI) was the main predictor variable. Using cutoffs recommended by WHO, the study participants was categorized as follows: normal (≥18.5 and <25.0 kg/m^2), overweight (≥25.0 and <30.0 kg/m^2), and obese (≥30 kg/m^2) (23).

Participant age was categorized as 35-44, 45-59, or ≥60 years. Educational status was based on the number of years of education and was categorized as low (0-8 years), intermediate (9-11 years), or high (>11 years). Tooth brushing and proximal tooth cleaning frequency were dichotomized as ≤1 time/day versus ≥2 times/day and <1 time/day versus ≥1 time/day, respectively. Dental care in the last 3 years was dichotomized as irregular (no dental visit or visits only for emergencies) versus regular (visits for prevention with a frequency of ≥2 times/year). Former and current smokers were considered to have had exposure to cigarette smoking. The number of packs of cigarettes consumed in a lifetime (pack-years) was calculated by multiplying the number of cigarettes consumed per day by the years of habit, divided by 20. Individuals were classified as never-smokers (0 pack-years), moderate smokers (<20 pack-years), or heavy smokers (≥20 pack-years). Gingivitis was categorized according to the percentage of bleeding sites on probing (≤20%, 21% to 59%, and ≥60%). The number of retained teeth and number of teeth with recession of ≥1 mm were modeled as continuous variables.

Data analysis was performed using the STATA software (Stata 11.1 for Windows, Stata Corporation, College Station, Texas, USA). A sampling weight variable was computed using census information provided by the Brazilian Institute of Geography and Statistics. Complex survey commands were applied to account for cluster correlations expected for the multistage sampling strategy used in this study. Pair-wise comparisons of crude estimates were performed using the Wald test. The significance level was set at 5%. Survey negative binomial regression model was applied to assess the relationship between weight status and caries experience. Estimates were adjusted for socio-demographic, behavioral, and clinical variables. A preliminary analysis using univariate models was performed, and variables showing associations with a *P*<0.25 were added to the multivariate models. Maintenance of variables in the final model was determined by a combination of a *P*<0.05 and analyses of confounders and interactions (24). Incidence rate ratios (IRR) and 95% CIs were estimated and reported.

Results

A total of 1,600 individuals were eligible for the Caries-Perio Collaboration Survey (Figure 1). Of them, 375 (23.43%) did not participate in the survey (non-respondents), resulting in a final sample of 1,225 (76.56%) individuals. The present sub-study included 1,002 dentate individuals, among which 394 (39.32%) were men and 608 (60.68%) were women aged 35-95 years.

Table 1 shows the weight status according to age. The overall prevalence of excessive body weight was 71.13% (95% CI 66.39-75.87), of which 39.80% (95% CI 35.18-44.41) were overweight and 31.33% (95% CI 26.50-36.16) were obese individuals.

Table 2 shows coronal and root caries experience by socio-demographic and behavioral characteristics, and weight status. The total mean coronal DMFT and root DFT scores was 18.68 (95% CI 18.24-19.13) and 1.14 (95% CI 0.95-1.34), respectively. Coronal DMFT scores did not significantly differ according to tooth brushing frequency and dental care frequency, whereas root DFT scores did not significantly differ according to educational status and proximal tooth cleaning frequency. No significant differences in coronal and root caries experience were found among the weight status groups.

In the univariate and multivariate models, coronal caries experience was not significantly associated with overweight and obesity (Table 3). In the adjusted analysis, women (IRR 1.09, 95% CI 1.05-1.14), age groups of 45-59 years (IRR 1.31, 95% CI 1.20-1.42) and

≥60 years (IRR 1.40, 95% CI 1.30-1.50), and a proximal tooth cleaning frequency of ≥1 time/day (IRR 0.94, 95% CI 0.91-0.98) emerged as risk indicators for coronal caries experience.

As shown in Table 4, root caries experience was not significantly associated with overweight and obesity in both univariate and multivariate models. In the adjusted model, a high educational status (IRR 1.76, 95% CI 1.02-3.07), higher coronal DMFT scores (IRR 1.11, 95% CI 1.07-1.15), a lower number of retained teeth (IRR 0.92, 95% CI 0.89-0.95), and a higher number of teeth with recession (IRR 1.15, 95% CI 1.15-1.22) were significantly associated with increased root DFT scores.

Discussion

The present study was conducted to assess the relationship of overweight and obesity with coronal and root caries experience among adults and the elderly from southern Brazil. Overweight and obesity were not significantly associated with coronal and root caries experience using both unadjusted and adjusted models. To the best of the authors' knowledge, this was the first population-based study to investigate the weight status and dental caries in individuals aged ≥35 years.

Our findings showed that more than 50% of the study population was overweight or obese, which is consistent with reports suggesting that the prevalence of both conditions is likely to increase (5, 6). A high-sugar diet has been identified as potential contributor to the overweight and obesity epidemic (8, 9). Because dental caries is strongly associated with the sugar intake (10), a common risk prevention approach could be applied for both dental caries and excessive body weight. Over the past few years, many studies have tested the hypothesis that children and adolescents who are overweight or obese are at increased risk for dental caries, but conflicting results have been found (11-17). This could indicate that overweight and obesity are not associated with dental caries in younger populations. In fact, a population-based study including Brazilian schoolchildren aged 12 years did not find any relationship of overweight and obesity with the prevalence and extent of dental caries after adjusting for sex, socioeconomic status, and tooth brushing frequency (15).

This growing body of evidence regarding the relationship of overweight and obesity with dental caries should also include adults and older people for two reasons. Firstly, recent improvements in overall health status have increased the mean life expectancy (25) and retention of teeth throughout life (26). Secondly, the increased prevalence of overweight and obesity may be correlated with increased age (7). Our study assessed an adult and elderly population and found that overweight and obesity were not significantly associated with coronal and root caries experience. Similarly, using self-reported tooth loss as outcome, a study including 4,483 Brazilian civil servants aged ≥60 years showed no significant association with overweight and obesity in this age group (27).

Our findings contradicts the concept that high-sugar diet is a common risk factor for dental caries and excessive body weight. In fact, reports investigating the relationship between high sugar-sweetened beverage consumption and weight status have shown controversial results (8, 9, 28). A prospective study involving three separate cohorts that included 120,877 women and men with a 20-year follow-up in the United States indicated a potential role of sugar-sweetened beverage consumption in promoting long-term weight gain after applying multivariate models adjusted for age, baseline BMI for each period, and lifestyle factors (8). Furthermore, a systematic review and meta-analysis including 32 prospective cohort studies and randomized clinical trials provide evidence that high sugar-sweetened beverage consumption promotes weight gain in children and adults (9). In contrast, a recent systematic review evaluating 14 observational studies published between 2001 and 2013 found that the relationship between sugar-sweetened beverage consumption and obesity risk was inconsistent for children, adolescents, and adults (28). Therefore, it is plausible to suggest that overweight and obesity may be associated with other types of diet. According to Brazilian data from the Telephone Monitoring System for Risk and Protection Factors for Chronic Diseases (VIGITEL), 53.5% of the participants aged ≥18 years ingested milk with significant fat content and 31% of the participants consumed fatty meat (29). This could explain, at least in part, the high prevalence of overweight and obesity in Brazil.

Our study has certain limitation. As described previously, our study was cross-sectional in nature. For this reason, the causal and temporal relationships of overweight and obesity with coronal and root caries experience remain unclear because it is not possible to determine which condition was firstly established. However, the present study provides useful data for further prospective cohort investigations.

In conclusion, the present study found that overweight and obesity were not associated with coronal and root caries experience among adults and the elderly from southern Brazil. Therefore, our findings indicate that overweight and obese individuals should not be considered at high risk for both coronal and root caries.

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Tables

Table 1. Excessive body weight according to age.

	Age, years			
	35-44, % (95% CI)	45-59, % (95% CI)	≥60, % (95% CI)	Total, % (95% CI)
Overweight	39.36 (29.16-49.56)[a]	38.30 (31.99-44.40)[b]	43.12 (36.08-50.15)[c]	39.80 (35.18-44.41)
Obese	33.18 (25.32-41.04)[a]	31.93 (28.97-34.90)[b]	27.36 (15.85-38.87)[c]	31.33 (26.50-36.16)
Total	72.55 (63.68-81.41)[a]	70.14 (65.45-74.83)[b]	70.48 (59.12-81.84)[c]	71.13 (66.39-75.87)

95% CI, 95% confidence interval.
Different letters indicate a statistically significant difference between categories using the Wald test ($P \leq 0.05$).

Table 2. Study sample distribution and coronal and root caries experience according to socio-demographic and behavioral characteristics, and weight status.

	n (%)	Coronal caries		Root caries	
		DMFT (95% CI)	*P*[a]	DFT (95% CI)	*P*[a]
Sex					
Male	394 (39.32)	17.79 (17.33-18.26)	ref.	1.37 (1.10-1.64)	ref.
Female	608 (60.68)	19.45 (18.72-20.18)	0.001	0.95 (0.74-1.16)	0.004
Age, years					
35-44	271 (27.05)	15.31 (14.41-16.22)	ref.	0.55 (0.33-0.76)	ref.
45-59	471 (47.01)	20.12 (19.59-20.65)	<0.001	1.42 (1.07-1.76)	0.001
≥60	260 (25.95)	21.76 (20.76-22.77)	<0.001	1.66 (1.26-2.07)	<0.001
Educational status					
Low	570 (56.89)	19.33 (18.63-20.04)	ref.	1.08 (0.90-1.26)	ref.
Intermediate	323 (32.24)	18.52 (17.78-19.26)	0.09	1.10 (0.91-1.29)	0.88
High	109 (10.88)	16.71 (15.14-18.27)	0.01	1.48 (0.42-2.54)	0.41
Tooth brushing frequency					
≤1 time/day	114 (11.38)	20.27 (18.65-21.90)	ref.	1.91 (1.18-2.64)	ref.
≥2 times/day	888 (88.62)	18.45 (17.86-19.05)	0.06	1.03 (0.88-1.19)	0.01
Proximal tooth cleaning frequency					
<1 time/day	518 (51.70)	19.27 (18.91-19.63)	ref.	1.21 (1.05-1.37)	ref.
≥1 time/day	484 (48.30)	18.03 (17.26-18.80)	0.004	1.07 (0.80-1.35)	0.20
Dental care frequency					
None or irregular	773 (77.15)	19.16 (18.52-19.80)	ref.	1.27 (0.97-1.56)	ref.
Regular	229 (22.85)	17.19 (15.46-18.92)	0.06	0.76 (0.55-0.97)	0.02
Exposure to cigarette smoking					
Never-smoker	454 (45.31)	18.62 (17.91-19.32)	ref.	0.81 (0.62-1.00)	ref.
Moderate smoker	293 (29.24)	17.81 (16.56-19.06)	0.29	1.22 (0.82-1.62)	0.01
Heavy smoker	255 (25.45)	20.09 (19.29-20.90)	0.006	1.73 (1.30-2.16)	0.002
Weight status					
Normal	272 (27.15)	18.48 (18.23-19.45)	ref.	1.33 (1.07-1.59)	ref.
Overweight	412 (41.12)	18.63 (17.69-19.57)	0.68	1.16 (0.88-1.44)	0.35
Obese	318 (31.74)	18.60 (17.80-19.41)	0.63	0.96 (0.65-1.27)	0.08
Total	1,002 (100.00)	18.68 (18.24-19.13)		1.14 (0.95-1.34)	

95% CI, 95% confidence interval.
[a]Wald test.

Table 3. Association between coronal caries experience and explanatory variables (unadjusted and adjusted negative binomial regression analysis).

	Unadjusted model		Adjusted model	
	IRR (95% CI)	*P*	IRR (95% CI)	*P*
Sex				
Male	1.00		1.00	
Female	1.09 (1.04-1.14)	0.001	1.09 (1.05-1.14)	<0.001
Age, years[a]				
35-44	1.00		1.00	
45-59	1.31 (1.21-1.41)	<0.001	1.31 (1.20-1.42)	<0.001
≥60	1.42 (1.32-1.52)	<0.001	1.40 (1.30-1.50)	<0.001
Educational status[a]				
Low	1.00		1.00	
Intermediate	0.95 (0.90-1.00)	0.09	0.99 (0.94-1.05)	0.96
High	0.86 (0.77-0.96)	0.01	0.89 (0.78-1.01)	0.08
Tooth brushing frequency				
≤1 time/day	1.00			
≥2 times/day	0.91 (0.82-1.00)	0.06		
Proximal tooth cleaning frequency				
<1 time/day	1.00		1.00	
≥1 time/day	0.93 (0.89-0.97)	0.006	0.94 (0.91-0.98)	0.01
Dental care frequency				
None or irregular	1.00			
Regular	0.89 (0.79-1.01)	0.07		
Exposure to cigarette smoking				
Never-smoker	1.00			
Moderate smoker	0.95 (0.87-1.04)	0.30		
Heavy smoker	1.07 (1.02-1.13)	0.006		
Weight status[a]				
Normal	1.00		1.00	
Overweight	0.98 (0.93-1.05)	0.68	0.98 (0.94-1.03)	0.62
Obese	0.98 (0.93-1.04)	0.63	0.98 (0.92-1.04)	0.55
Gingivitis				
≤20%	1.00			
21% to 59%	0.99 (0.93-1.05)	0.86		
≥60%	1.09 (1.02-1.17)	0.008		

IRR, incidence rate ratio; 95% CI, 95% confidence interval.
[a]Variables maintained in the final model independently of the *P*-value.

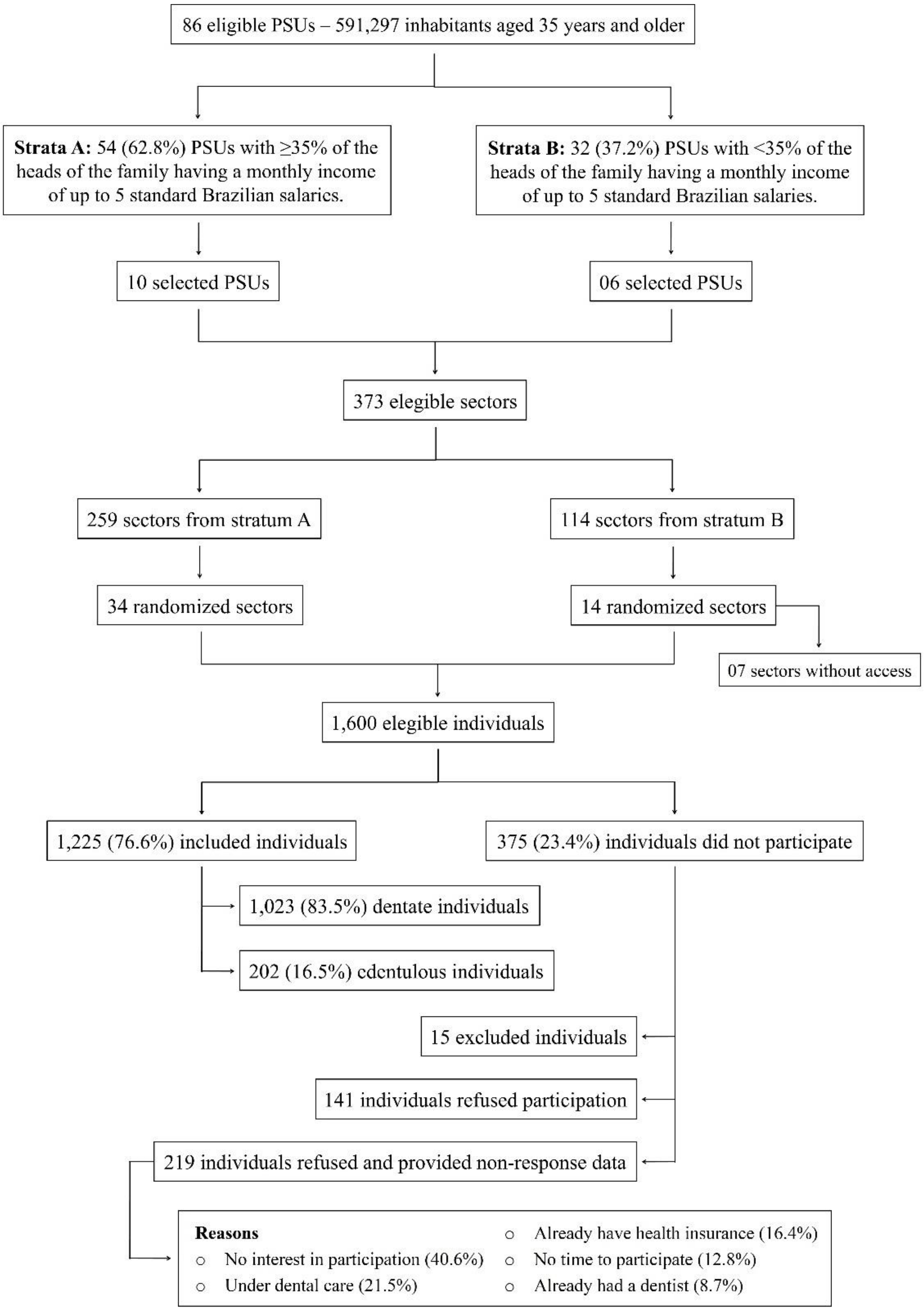
Table 4. Association between root caries experience and explanatory variables (unadjusted and adjusted negative binomial regression analysis).

	Unadjusted model		Adjusted model	
	IRR (95% CI)	*P*	IRR (95% CI)	*P*
Sex				
Male	1.00			
Female	0.69 (0.55-0.87)	0.005		
Age, years[a]				
35-44	1.00		1.00	
45-59	2.56 (1.53-4.29)	0.002	1.06 (0.71-1.60)	0.73
≥60	3.01 (2.00-4.53)	<0.001	1.12 (0.75-1.67)	0.52
Educational status[a]				
Low	1.00		1.00	
Intermediate	1.01 (0.79-1.30)	0.88	1.08 (0.88-1.34)	0.39
High	1.36 (0.69-2.70)	0.33	1.76 (1.02-3.07)	0.04
Tooth brushing frequency				
≤1 time/day	1.00			
≥2 times/day	0.54 (0.38-0.77)	0.003		
Proximal tooth cleaning frequency				
<1 time/day	1.00			
≥1 time/day	0.89 (0.72-1.09)	0.23		
Dental care frequency				
None or irregular	1.00			
Regular	0.60 (0.39-0.93)	0.02		
Exposure to cigarette smoking				
Never-smoker	1.00			
Moderate smoker	1.50 (1.16-1.93)	0.005		
Heavy smoker	2.13 (1.42-3.19)	0.002		
Weight status[a]				
Normal	1.00		1.00	
Overweight	0.86 (0.63-1.19)	0.35	0.99 (0.67-1.45)	0.96
Obese	0.72 (0.48-1.07)	0.09	1.01 (0.69-1.50)	0.91
Gingivitis				
≤20%	1.00			
21% to 59%	0.94 (0.61-1.44)	0.76		
≥60%	0.89 (0.52-1.53)	0.65		
Coronal DMFT scores	1.09 (1.07-1.12)	<0.001	1.11 (1.07-1.15)	<0.001
No. of retained teeth	0.96 (0.94-0.97)	<0.001	0.92 (0.89-0.95)	<0.001
No. of teeth with recession	1.06 (1.05-1.08)	<0.001	1.15 (1.15-1.22)	<0.001

IRR, incidence rate ratio; 95% CI, 95% confidence interval.
[a]Variables maintained in the final model independently of the *P*-value.

Figure legends

Figure 1. Flowchart of sampling strategy and response rate (PSU = primary sampling unit).


86 eligible PSUs – 591,297 inhabitants aged 35 years and older
Strata A: 54 (62.8%) PSUs with ≥35% of the heads of the family having a monthly income of up to 5 standard Brazilian salaries.
Strata B: 32 (37.2%) PSUs with <35% of the heads of the family having a monthly income of up to 5 standard Brazilian salaries.
10 selected PSUs
06 selected PSUs
373 elegible sectors
259 sectors from stratum A
114 sectors from stratum B
34 randomized sectors
14 randomized sectors
07 sectors without access
1,600 elegible individuals
1,225 (76.6%) included individuals
375 (23.4%) individuals did not participate
1,023 (83.5%) dentate individuals
202 (16.5%) edentulous individuals
15 excluded individuals
141 individuals refused participation
219 individuals refused and provided non-response data
Reasons
No interest in participation (40.6%)
Under dental care (21.5%)
Already have health insurance (16.4%)
No time to participate (12.8%)
Already had a dentist (8.7%)