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A multilevel analysis model for dental caries determinants in independently-living elderly

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Aim: To evaluate the prevalence of untreated caries and its association with biological, individual, and environmental variables in independently-living elderly people. **Methods:** This cross-sectional study included 72 elderly (≥60 years) patients of a university dental clinic in Belo Horizonte, Brazil. Sociodemographic data, systemic diseases, medications, and free sugar intake were collected. Visible plaque, Decayed, Missing, and Filled Teeth (DMFT), and Decayed and Filled Root (DFR) indexes were assessed through clinical examination. Unstimulated saliva was collected to determine salivary flow, pH, and buffering capacity. Descriptive analysis and multilevel logistic regression analysis were performed following a dental caries theoretical model (p <0.05, 95% CI). **Results:** The mean DMFT and DFR were 24.44 (SD=4.59) and 3.21 (SD=2.93), respectively. The prevalence of untreated caries was 61.11%. In the adjusted multilevel regression model involving 1639 teeth, untreated dental caries was significantly associated with the presence of biofilm (OR = 1.84; 95% CI: 1.24–2.74), salivary buffering capacity (OR = 0.87; 95% CI: 0.77–0.99) and per capita income (OR = 0.06; 95% CI: 0.004–0.74). **Conclusion:** The experience of dental caries was widespread among independently-living elderly patients, and its variability was best explained by the presence of biofilm, reduced salivary buffering capacity, and low per capita income. A comprehensive assessment is needed of the biological, individual, and environmental factors related to the presence of dental caries in independently-living elderly people.

Keywords: Aged. Dental caries. Saliva. Oral Health.

Introduction

Recent years have been characterized by important changes in the global demographic profile, with increased population aging and people retaining their teeth for longer[1]. The aging process is related to decreased motor capacity, difficulty with oral hygiene, and an increased risk for the development of chronic diseases that require medicine[2]. Local and systemic conditions may affect the oral environment, increasing the occurrence of dental caries in elderly people[2]. Accordingly, the prevalence of untreated dental caries peaks in the elderly population worldwide[3], playing an important role in decreasing their quality of life[3].

Dental caries is a multifactorial and dynamic disease, mediated by biofilm and modulated by the diet but also determined by biological, individual, and environmental factors[4]. A decrease in plaque pH—caused by increased intake of fermentable carbohydrates or reduced salivary flow—can facilitate tooth demineralization, as it favors the growth of potentially cariogenic bacteria[5-7]. Saliva is one of the determining factors in the development of dental caries: a reduction in salivary flow can affect the protective properties of saliva, increasing the risk of and susceptibility to dental caries[8-11]. This condition becomes more serious in older people, primarily due to systemic changes and the use of medications that potentially reduce the salivary flow[12,13]. Other salivary parameters, such as pH and buffering capacity, have not yet shown definitive associations with dental caries. Theoretical models of dental caries also include demographic, social, and economic factors as important determinants of the disease[14,15].

Data on dental caries in elderly people in Latin American countries are still limited, even given the demographic transition occurring in this region[16]. Brazilian surveys reported high prevalence and experience of dental caries in older Brazilian people[17-19]. While epidemiological studies with elderly patients seek to analyze the complexity of various variables, they fail to consider the biological aspects of dental caries[10,17,20-23]. An understanding of dental caries should incorporate biological and environmental concepts, including social, contextual, and behavioral aspects, in order to construct a more robust analysis model[15]. Thus, this cross-sectional study evaluated the prevalence of untreated caries and their association with biological, individual, and environmental variables in Brazilian independently-living elderly people. The null hypothesis tested in this study stated that biological, individual, and environmental variables would not influence the occurrence of untreated dental caries.

Materials and Methods

Ethical considerations

The study was conducted according to the Declaration of Helsinki and was approved by the Research Ethics Committee of the Federal University of Minas Gerais (CAAE: 12045119.7.0000.5149). All participants signed an informed consent form.

The Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) recommendations were followed in the reporting of this cross-sectional study.

Selection of participants

A non-probabilistic convenience sample was recruited from the population of patients treated at dental clinics in Federal University of Minas Gerais, employees, and members of the academic community continuously from August to December 2019.

To be eligible, participants had to be 60 years of age or more (which is the minimum age to be classified as elderly in Brazil), living independently, and able to undergo the saliva collection procedure. We excluded patients who had undergone or were undergoing head and neck radiotherapy, patients with Sjögren›s syndrome, and residents of long-term institutions.

A sample size of 71 participants was estimated from the data of a pilot study conducted with 15 patients, given an absolute precision of 5%, a frequency of untreated caries of 93%, and a confidence interval of 90% (https://www.openepi.com/SampleSize/SSPropor.htm).

Data collection

A trained examiner performed all clinical examinations (intra and inter-examiner kappa coefficient agreement >0.85) using a flat clinical mirror and the World Health Organization (WHO)'s model probe under artificial lighting in a dental chair. The WHO guidelines[24] were used to collect data for the Decayed, Missing, and Filled Teeth (DMFT), Decayed, Missing, and Filled Teeth Surfaces (DMFS), and Decayed and Filled Roots (DFR) indices. The outcome measure was the prevalence of untreated caries corresponding to coronal or root decay, in spite of lesion activity.

The same examiner interviewed all participants to collect data related to sociodemographic characteristics, such as sex, age, marital status, income, and education level, as well as possible systemic diseases and medications currently used. Participants with five or more pathologies were classified as having polypathology[25], and the use of five or more drugs was classified as polypharmacy[25]. The visible plaque index was established before the examination and was used to assess the presence or absence of visible plaque on the buccal and lingual surfaces of each tooth[26].

Saliva collection and analysis

Unstimulated saliva was collected in identified plastic containers and stored on ice in Styrofoam containers. Collections were conducted in the morning, and participants were instructed to keep a 1-hour fast before the collection. The participants were instructed to remain at rest, seated, without performing movements of swallowing, chewing, or speaking[27], and the salivary fluid at rest was collected for five minutes, for subsequent determination of the salivary volume and salivary flow per minute. Values equal to or less than 0.1 mL/min were classified as hyposalivation, and higher values were classified as normal salivation[8].

The salivary pH was determined using colorimetric pH test strips (Saliva-Check BUFFER®, GC America Inc., Alsip, USA). In line with the manufacturer's instructions, the pH value was established and classified as follows: highly acidic (5.0–5.8), moderately acidic (6.0–6.6), and healthy (6.8–7.8). The salivary buffering capacity was

also assessed using strips (Saliva-CheckBUFFER®, GC America Inc., Alsip, USA), wherein values ranged from 0 to 12 and were classified as very low (0–5), low (6–9), and normal/high (10–12).

Diet assessment

A 24-hour recall was used to collect diet data[28]. This method facilitates participant recall because it deals with a short time period, thus proving to be suitable for use with elderly participants. Once the data was obtained, the Nutrition Support Program–NutWin Version 1.6 (São Paulo, Brazil), was used to calculate the daily caloric intake and the percentage of free sugar ingested.

Statistical analysis

All data collected were analyzed using IBM SPSS Statistics® Version 19 software for descriptive analysis; then data were imported into Stata® Version 15 software for the bivariate and multivariate analyses. The outcome or dependent variable was the presence of untreated caries in each tooth evaluated, including both coronal and root decay. The null model was built with the dependent variable to verify the feasibility of multilevel analysis: it was reasonable, since the variance proportion of dental caries was expected to vary among individuals (ICC=0.374).

For performance of the analysis, the studied variables were categorized. Visible plaque was evaluated as present or absent; age was categorized as 60–69 years and ≥70 years; sex was categorized as female and male; self-declared race was categorized as white and non-white; marital status was categorized as married and not married; per capita income was categorized according to the minimum wage received (considered R$980.00 in Brazil in 2019); education level was categorized according to the number of years studied; and presence or absence of systemic diseases included polypathology, hypertension, diabetes, reflux, use of medication, polypharmacy, and use of anti-hypertensives, antidepressants, and proton pump inhibitors. Salivary flow was considered to be normal or reduced (hyposalivation); salivary pH was considered healthy or moderately acidic; and salivary buffering capacity was considered normal/high, low, or very low. In addition, the same salivary features and the percentage of free sugar intake were evaluated as quantitative variables.

Bivariate analysis was performed to obtain the odds ratio (OR) and the confidence interval (95% CI) values. Variables with a *p*-value of <0.25 were included in the multilevel analysis via logistic regression, along with variables of the theoretical model, based on Holst et al.[15] (2001) (Fig. 1). Multilevel analysis initially included variables at the tooth level in model 1, followed by the biological variables (i.e., sugar intake and salivary characteristics) that act at the individual level in model 2. The environmental and non-biological factors related to demographic and socioeconomic variables were included in model 3, which improved the explanation of the outcome variance. The likelihood-ratio test was used to compare the models. Only variables with a significance level of 5% ($p < 0.05$) were considered to be associated with the presence of untreated dental caries.

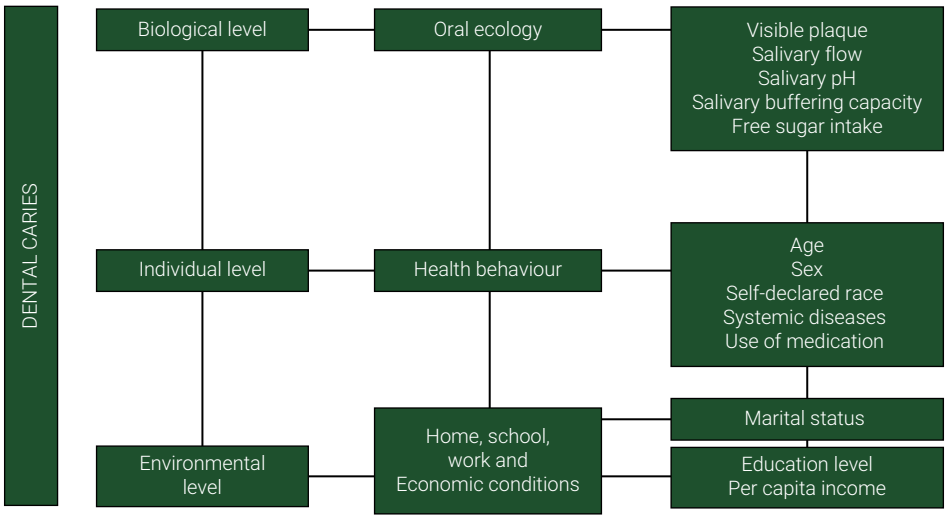

Figure 1. Theoretical model including biological, individual, and environmental variables. Based on Holst et al.[15] (2001)

Results

This study involved 72 participants, whose ages ranged from 60 to 84 years, with a mean age (SD) of 67.29 (6.12) years (median age = 66 years). Most participants were female (55.6%), had at least one systemic disease (81.9%), and used at least one medication (79.2%). The mean (SD) salivary flow rate was 0.61 (0.34) mL/minute, the mean (SD) salivary pH was 6.9 (0.45), and the mean (SD) salivary buffering capacity was 7.2 (3.07).

In terms of dental caries, 44 participants (61.11%) had at least one decayed tooth; this number includes 26 (36.11%) who had at least one tooth with root caries. The mean DMFT index was 24.44 (SD=4.59), and the mean DFR index was 3.21 (SD=2.93). The mean number of decayed teeth per person was 1.76, including 0.75 decayed roots per person (Table 1).

Table 1. Descriptive analysis of dental caries in Brazilian elderly ranging from 60 to 84 years old

	n	%
Dental caries (crown and root)		
With caries	44	61.11
Without caries	28	38.89
Root caries		
With root caries	26	36.11
Without root caries	46	63.89
	Mean (SD)	**Median (IR)**
DMFT	24.44 (4.59)	26.00 (5.00)

Continue

Continuation		
DMFS	84.32 (22.74)	85.50 (36.00)
DFR	3.21 (2.93)	2.50 (4.00)
Decayed tooth	1.76 (2.18)	1.00 (3.00)
Decayed root	0.75 (1.44)	0.00 (1.00)

DMFT= Decayed, Missing and Filled Teeth; DMFS= Decayed, Missing and Filled Surface; DFR= Decayed and Filled Root; SD=standard deviation; IR=interquartile range

Bivariate analysis indicated associations ($p < 0.25$) between the presence of dental caries and visible plaque, age, self-declared race, per capita income, education level, use of proton pump inhibitors, salivary buffering capacity, and percentage of free sugar intake (Table 2).

Table 2. Descriptive and bivariate analysis of independent variables associated with untreated dental caries

Categorical variables	Without Dental Caries		With Dental Caries		Bivariate analysis		
	n	%	n	%	OR	95% CI	*P* value
Visible Plaque							
No	2	66.7	1	33.3		[1-1]	
Yes	21	30.4	48	69.6	**1.89****	**[1.28-2.80]**	**(0.001)**
Age							
60-69 years	19	38.0	31	62.0		[1-1]	
≥ 70 years	4	18.2	18	81.8	2.10	[0.92-4.78]	(0.077)
Sex							
Female	12	30.0	28	70.0		[1-1]	
Male	11	34.4	21	65.6	1.17	[0.54-2.55]	(0.691)
Self-declared race							
White	13	30.2	30	69.8		[1-1]	
Brown, yellow, black, indigenous	10	34.5	19	65.5	1.98	[0.93-4.23]	(0.076)
Marital status							
Married	16	30.8	36	69.2		[1-1]	
Not married	7	35.0	13	65.0	1.11	[0.46-2.65]	(0.821)
Per capita income[1]							
< 1 minimum wage	4	25.0	12	75.0		[1-1]	
1-3 minimum wage	7	28.0	18	72.0	0.75	[0.30-1.87]	(0.542)
3-5 minimum wage	5	41.7	7	58.3	0.34	[0.11-1.09]	(0.070)
5-10 minimum wage	2	16.7	10	83.3	0.54	[0.18-1.61]	(0.266)
> 10 minimum wage	5	83.3	1	16.7	**0.03****	**[0.002-0.34]**	**(0.005)**

Continue

Continuation							
Education level							
< 4 years	2	28.6	5	71.4		[1-1]	
4-7 years	1	10.0	9	90.0	0.61	[0.14-2.63]	(0.508)
8-10 years	1	11.1	8	88.9	0.66	[0.15-2.97]	(0.592)
≥ 11 years	19	41.3	27	58.7	**0.27***	**[0.08-0.92]**	**(0.036)**
Systemic diseases							
No	3	23.1	10	76.9		[1-1]	
Yes	20	33.9	39	66.1	0.65	[0.24-1.74]	(0.392)
Polypathology							
No	20	32.3	42	67.7		[1-1]	
Yes	3	30.0	7	70.0	0.90	[0.29-2.81]	(0.860)
Hypertension							
No	13	31.7	28	68.3		[1-1]	
Yes	10	32.3	21	67.7	0.92	[0.42-2.02]	(0.840)
Diabetes							
No	18	32.1	38	67.9		[1-1]	
Yes	5	31.3	11	68.8	1.00	[0.39-2.57]	(0.995)
Reflux							
No	20	31.7	43	68.3		[1-1]	
Yes	3	33.3	6	66.7	0.58	[0.18-1.89]	(0.363)
Use of medication							
No	4	26.7	11	73.3		[1-1]	
Yes	19	33.3	38	66.7	0.64	[0.25-1.62]	(0.347)
Polypharmacy							
No	18	35.3	33	64.7		[1-1]	
Yes	5	23.8	16	76.2	1.00	[0.43-2.35]	(0.997)
Antihypertensives							
No	13	32.5	27	67.5		[1-1]	
Yes	10	31.3	22	68.8	1.32	[0.61-2.88]	(0.482)
Antidepressants							
No	19	33.9	37	66.1		[1-1]	
Yes	4	25.0	12	75.0	1.25	[0.49-3.17]	(0.640)
Proton pump inhibitors							
No	20	32.3	42	67.7		[1-1]	
Yes	3	30.0	7	70.0	0.47	[0.15-1.50]	(0.201)
Salivary flow							
Normal	23	33.3	46	66.7		1 [1-1]	
Hypossalivation	0	0.0	3	100.0	1.89	[0.30-11.99]	(0.499)

Continue

Continuation							
Salivary pH							
Healthy saliva	16	34.8	30	65.2		1 [1-1]	
Moderately acidic	7	26.9	19	73.1	0.90	[0.40-2.02]	(0.797)
Salivary buffering capacity							
Normal / High	6	30.0	14	70.0		1[1-1]	
Low	11	40.7	16	59.3	0.86	[0.33-2.25]	(0.761)
Very low	6	24.0	19	76.0	2.22	[0.87-5.70]	(0.096)
Quantitative variables	**Mean (SD)**		**Median (IR)**				
Salivary flow (mL/min)	0.61 (0.34)		0.60 (0.40)		1.12	[0.35-3.60]	(0.853)
Salivary pH	6.90 (0.45)		6.90 (0.95)		1.00	[0.42-2.38]	(0.995)
Salivary buffering capacity	7.20 (3.07)		7.00 (5.00)		**0.87***	**[0.77-0.98]**	**(0.021)**
Percentage of free sugar intake	9.17 (9.30)		6.48 (12.39)		0.97	[0.93-1.01]	(0.165)

[1]one missing data; SD=standard deviation; IR=interquartile range; OR=odds ratio; IC=confidence interval;
* p < 0.05; ** p < 0.01

Table 3 presents the multilevel analysis of variables associated with untreated dental caries. The adjusted final model shows a significant association of untreated dental caries with visible plaque (variable at the tooth level); moreover, untreated dental caries was further explained at the individual level by the biological variable of salivary buffering capacity and the non-biological variable of income per capita ($p < 0.05$). The presence of visible plaque represented a risk factor for dental caries (OR = 1.84), while buffering capacity acted as a protective factor (OR = 0.87), meaning that for each one-point increase in the buffering capacity, the individual is 13% more protected. Finally, participants with a high income had a lower risk of developing caries (OR = 0.06).

Table 3. Multilevel analysis of variables associated with untreated dental caries

	Null model	Model 1		Model 2		Adjusted final model	
		OR	95% CI	OR	95% CI	OR	95% CI
2* log likelihood	-957.708	-947.63		-939.064		-890.922	
Tooth level (n=1639)							
Visible Plaque							
No		1	[1-1]	1	[1-1]	1	[1-1]
Yes		1.89**	[1.28-2.80]	1.84**	[1.25-2.72]	1.84**	[1.24-2.74]
Individual level (n=72)							
Quantitative variables							
Percentage of free sugar intake				0.96	[0.92-1.00]	0.97	[0.93-1.02]
Salivary buffering capacity				0.85**	[0.76-0.96]	0.87*	[0.77-0.99]

Continue

Continuation		
Categorical variables		
Sex		
Female	1	[1-1]
Male	0.95	[0.48-1.91]
Age		
60-69 years	1	[1-1]
≥ 70 years	1.48	[0.67-3.30]
Self-declared race		
White	1	[1-1]
Brown, yellow, black, indigenous	1.21	[0.52-2.80]
Education level		
< 4 years	1	[1-1]
4-7 years	1.04	[0.23-4.80]
8-10 years	1.00	[0.19-5.34]
≥ 11 years	0.82	[0.15-4.60]
Per capita income		
< 1 minimum wage	1	[1-1]
1-3 minimum wage	1.17	[0.36-3.75]
3-5 minimum wage	0.52	[0.12-2.26]
5-10 minimum wage	0.89	[0.21-3.83]
> 10 minimum wage	0.06*	[0.004-0.74]
Proton pump inhibitors		
No	1	[1-1]
Yes	0.68	[0.23-2.05]

OR=odds ratio; IC=confidence interval; * p < 0.05, ** p < 0.01

Discussion

This cross-sectional study showed a high frequency of untreated caries in independently-living elderly people. The null hypothesis—i.e., that biological, individual, and environmental variables will not influence the occurrence of untreated caries—was rejected. The presence of dental caries was associated with biological factors at the tooth level (presence of visible plaque) and the individual level (salivary buffering capacity), together with an environmental factor (income per capita). The multilevel analysis is a novelty in the field, as previous studies have not yet approached caries among elderly people using such a model.

The frequency of observed dental caries is similar to those reported in previous studies conducted in Brazil[17,18] and India[20]. However, our values are higher than those reported in certain other countries—Uruguay[29], the United States[10], and Norway[21]—and

lower than those reported in China[22]. The present data demonstrate heterogeneity in the distribution of dental caries but also consistency as a common disease in elderly people. In Brazil, elderly people are still characterized by premature and high tooth loss. In the last Brazilian epidemiological survey[19], the mean DMFT was 27.53 for the elderly population, with a mean of 0.23 decayed roots per person—a value lower than that in our study.

It is already known that dental caries is mediated by biofilm and modulated by diet[4,5]. We showed that the presence of visible plaque was a risk factor for the disease, in line with the current literature[18,23,30]. However, free sugar intake had no significant association in the present study, despite being a known risk factor for tooth decay[31]. The 24-hour recall was chosen as a simple-to-use instrument that suitable for helping elderly patients remember their food from the day before the appointment; however, its subjective character allows for the report to be less accurate in terms of what actually happened, leading to possible bias. At the same time, assessing the frequency of eating sugars could be more sensitive than the total consumption of sugars, even though the relative importance of the amount and frequency of sugar intake for caries development has been a matter of debate in recent years[32].

Our results show that when the saliva neutralization capacity is increased, elderly patients are less likely to develop tooth decay. A protective association between dental caries and salivary buffering capacity has been previously reported[11,33]; however, studies with elderly people are still rare and contradictory. One study related a lower incidence of root caries with high salivary buffering capacity[23], while other studies have reported no associations between this property of saliva and dental caries[9] or the experience of root caries[30].

Salivary flow did not relate significantly to dental caries, as already shown in elderly Brazilians[18]. However, it was expected that the flow of saliva would also act as a protective factor in this study, in line with other existing results[11]. Most studies report that older people with a reduced salivary flow are more likely to develop tooth decay[9,10,30]; in contrast, in the present study, the sample characteristics support this lack of association, since the participants were mostly younger, less fragile elders, and the great majority presented normal salivary flow.

Social, demographic, and economic factors are also determinants of the course of dental caries[5,15,29,34]. In this study, participants with a high income had a lower risk of developing caries. This may relate to the greater access to health services that is available to high-income patients, to the detriment of those who are poorer. Income is an important associated factor, as it can influence the patient's dietary habits, hygiene practices, and access to preventive and treatment measures[34]. Thus, public policies must focus on reducing social disparities that may interfere with the population's dental health.

The main limitation of this study is its convenience sample, which was recruited from a single center and thus could contain selection bias. Furthermore, since the sample includes patients attending a university clinic, employees, and members of the academic community, the results cannot be extrapolated to the entire population, and they should be interpreted with caution. However, a strength of the study is its use

of an estimated sample size and multilevel statistical analysis to follow a comprehensive theoretical model that considered both biological and non-biological factors contributing to the process of dental caries. Future studies should follow up on representative populations of elderly people and use medication dosage/frequency and sugar consumption frequency as explanatory variables.

In conclusion, this study identified a high prevalence of untreated dental caries in the independently-living elderly Brazilians evaluated. The variability of the disease seems to be best explained by the presence of dental biofilm, the salivary buffering capacity, and income per capita. Given its multifactorial character, the risk for dental caries must be evaluated in view of the different contexts in which the elderly patient exists in order to facilitate diagnosis, prevention, and treatment.

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Data Availability

Datasets related to this article will be available upon request to the corresponding author.

Conflicts of interest

None.

Author Contribution

Designed the study: N.T.T.B, I.M.A.D. A.N.M. and C.S.M. Performed data collection: N.T.T.B and J.V.R.S. Analyzed the data: N.T.T.B, C.S.M. and R.C.F. Wrote and revised the manuscript: N.T.T.B., I.M.A.D., R.C.F., J.V.R.S., A.N.M. and C.S.M. All authors actively participated in the manuscript's findings and have revised and approved the final version of the manuscript.

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