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Tooth loss in Brazilian middle-aged adults: multilevel effects

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Abstract

Objective. To examine the link between tooth loss and multilevel factors in a national sample of middle-aged adults in Brazil. ***Material and methods.*** Analyses were based on the 2003 cross-sectional national epidemiological survey of the oral health of the Brazilian population, which covered 13 431 individuals (age 35–44 years). Multistage cluster sampling was used. The dependent variable was tooth loss and the independent variables were classified according to the individual or contextual level. A multilevel negative binomial regression model was adopted. ***Results.*** The average tooth loss was 14 (standard deviation 9.5) teeth. Half of the individuals had lost 12 teeth. The contextual variables showed independent effects on tooth loss. It was found that having 9 years or more of schooling was associated with protection against tooth loss (means ratio range 0.68–0.76). Not having visited the dentist and not having visited in the last ≥3 years accounted for increases of 33.5% and 21.3%, respectively, in the risk of tooth loss ($P < 0.05$). The increase in tooth extraction ratio showed a strong contextual effect on increased risk of tooth loss, besides changing the effect of protective variables. ***Conclusions.*** Tooth loss in middle-aged adults has important associations with social determinants of health. This study points to the importance of the social context as the main cause of oral health injuries suffered by most middle-aged Brazilian adults.

Key Words: *Adult health, multilevel models, oral health, regression analysis*

Introduction

Tooth loss is a recognized public health problem, is considered an important measure of the oral health of a population and has a powerful impact on quality of life. Its impacts include a decrease in the functional capabilities of mastication and speech, as well as a decline in nutritional, aesthetic and psychological status, with an associated negative effect in terms of self-esteem and social integration [1–4].

Even in developed countries, the loss of permanent teeth is high. In European countries, there have been few epidemiological studies of edentulism (complete loss of all natural teeth) and tooth loss. Müller et al. [5] have documented the decrease in edentulism, showing that there are large differences in prevalence between countries, between geographical regions within countries and between groups with various backgrounds. There are even significant differences between countries with seemingly similar economic and social conditions, such as the Nordic countries. In the 1990s, the prevalence of edentulism among 75-year-old subjects in a Swedish, a Danish and a Finnish city were 27%, 45% and 58%, respectively [5]. However, in countries such as Madagascar, the prevalence of edentulism in the elderly is only 25% [1]. Given the cumulative nature of the principal oral diseases (caries and periodontal disease), knowledge of the oral conditions of the middle-aged adult population is of special importance.

The causal factors for tooth loss involve both contextual and individual factors, with various gradients and interactions between them. This network fits into the ecosocial theory, as proposed by Krieger [6], which is a way of integrating biological and social knowledge with the structure of an object of a fractal

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nature, with inter-relationships between different variables at all levels, from molecular to social. Joint analysis of individual and ecological variables therefore corroborates investigation at multiple levels, given the complex hierarchy and multiple interactions between and across the different levels, which together make up what Susser and Susser [7] have called an eco-epidemiology.

The influence of individual and dental factors on tooth loss has already been the subject of several studies in various countries, which have included multilevel approaches [8–12]. Although analysis of contextual factors is the subject of ecological studies, analysis of the influence of the individual level controlled by the contextual level on the phenomenon of tooth loss could still contribute to a better understanding of the complexity of this phenomenon and its determining factors.

In Brazil, oral health has rarely been the subject of national epidemiological studies of the middle-aged adult and elderly population. Traditionally, both research and dental services have given priority to the oral health of schoolchildren. In spite of a well-established universal health system in the country, the management of tooth loss in adults is still hampered by the legacy of the former schoolchild model of dental care.

The aim of this study was thus to assess the effect of contextual and individual level predictors on tooth loss among Brazilians aged 35–44 years based on a cross-sectional epidemiological study of the oral health condition of the Brazilian population (SB Brazil Project).

Material and methods

Sampling process

Three-stage cluster sampling was used for the survey. Initially, municipalities were stratified by size of population into five categories. Subsequently, 50 municipalities were sampled in each of the five regions of Brazil (North, Northeast, Central West, Southeast and South) according to population size. Finally, households were sampled according to census sector and individuals in the eligible age group (35–44 years) were examined. In all, 250 municipalities were sampled. However, the clustering of participants within households was not considered, as this information was not provided.

The way in which the data were collected allows for the identification of four levels of hierarchy, which, at the level of analysis, were: (i) the five Brazilian regions, (ii) the 27 Brazilian states, (iii) the 250 municipalities sampled according to population size and (iv) the individuals who make up the sample unit. A control is thus provided for interdependence between municipality, state and the region of origin of the individuals.

Data collection

To ensure standardized data collection, dentists were trained as instructors and were then responsible for conducting training workshops for field workers (who were also dentists). Calibration of field teams was conducted by assessment of a random 10% of all data collected. Of the middle-aged adults (age 35–44 years) who participated in this survey, the total size of the sample was 13 431 individuals. Although the original plan had envisaged investigation of 250 municipalities, one municipality failed to carry out data collection.

Dependent and independent variables

The dependent variable was tooth loss, measured on a scale from 0 to 32. To avoid arbitrary cutoff points, the dependent variable was kept as a counting variable. Figure 1 presents the distribution of tooth loss in the sample in the form of a histogram and box plot.

At the individual level, the independent variables selected were geographical location, schooling, type of housing, automobile ownership, number of people per room in household, having visited a dentist, time of last visit to dentist, location of last visit to dentist, reason for last visit to dentist and information on prevention of oral diseases, sex, ethnic group and age.

At the contextual level, the independent variables were: (i) number of dentists/1000 inhabitants (regional level), (ii) tooth extraction ratio, defined as the number of extractions performed by public health services divided by the population of a given area (state level) and (iii) population size (municipal level). The variables for the regional and state levels were collected from the Department of Information Technology of the National Health System (DATASUS) records for the year 2003. Information on the population size of municipalities and the individual variables are available in the database of the epidemiological survey.

Statistics

Owing to the distribution of participants according to the number of teeth lost and to avoid the over-dispersion phenomenon (when the variance of the outcome variable is greater than the mean) [13], a negative binomial log-linear regression model was used. The exponential of the regression coefficient is a measure of the effect expressed as a means ratio

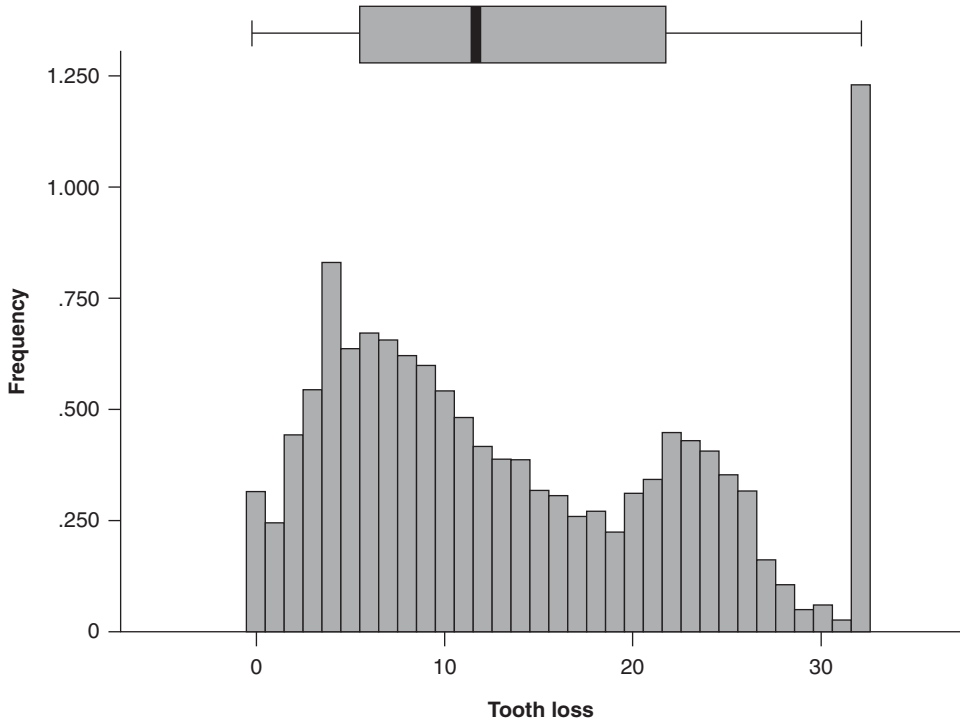

Figure 1. Histogram and box plot of the distribution of tooth loss in the sample.

(MR). The interpretation of this measure is similar to that of relative risk, and thus MR values > 1 suggest increased risk and those < 1 reduced risk of tooth loss. A multilevel regression with random intercept was used.

Estimates of MR were generated with the help of the statistical program MLwiN 2.02® [14]. The estimation process used was the iterative generalized least squares, using the procedure of penalized quasi-likelihood of second order. The *P*-value was estimated using the Wald test. Analysis of residuals was performed to check the fit of the final model.

The influence of the factors under study on tooth loss followed the hierarchical model proposed by Victora et al. [15]. Taking as a reference the conceptual model shown in Figure 2, each candidate variable within each given block was first analyzed using a univariate approach. Variables with $P < 0.20$ were considered in the multiple model. At each level, variables attaining a significance level of at least $P = 0.05$ were kept for adjustment of subsequent blocks.

Ethical considerations

The epidemiological survey and the present study were approved by the National Ethics Committee on Human Research and by the Ethics Committee on Human Research of the University of São Paulo's School of Public Health, respectively.

Results

The average tooth loss was 14 teeth (standard deviation 9.5). Half of the individuals had lost 12 teeth. Table I shows the composition of the sample and tooth loss according to the independent variables.

Table II presents the results of the multiple hierarchical model. It was observed that the contextual variables (block 1) retained statistical significance and showed independent effects on tooth loss. In block 2, schooling and automobile ownership alone remained in the final model and their effects were controlled by the variables at the contextual level. It was found that having ≥5 years of schooling and owning an automobile were associated with protection against tooth loss. The MRs for those who had ≥9 years of schooling and ≥2 automobiles were 0.723 and 0.763, respectively.

In block 3, the location of the last visit to the dentist did not remain in the final model. Even after controlling for the effects of higher blocks, having visited the dentist at least once in their life and not having visited in the last ≥3 years accounted for increases of 33.5% and 21.3%, respectively, in the risk of tooth loss. The greatest risk was observed in relation to bleeding gums, a swollen face or wounds in the mouth being the reason for the last visit to the dentist (MR = 1.387).

Both being aged above the median age and being female were associated with increases in the risk of tooth loss of 32.2% and 27.5%, respectively, regardless of the presence of the variables in the previous

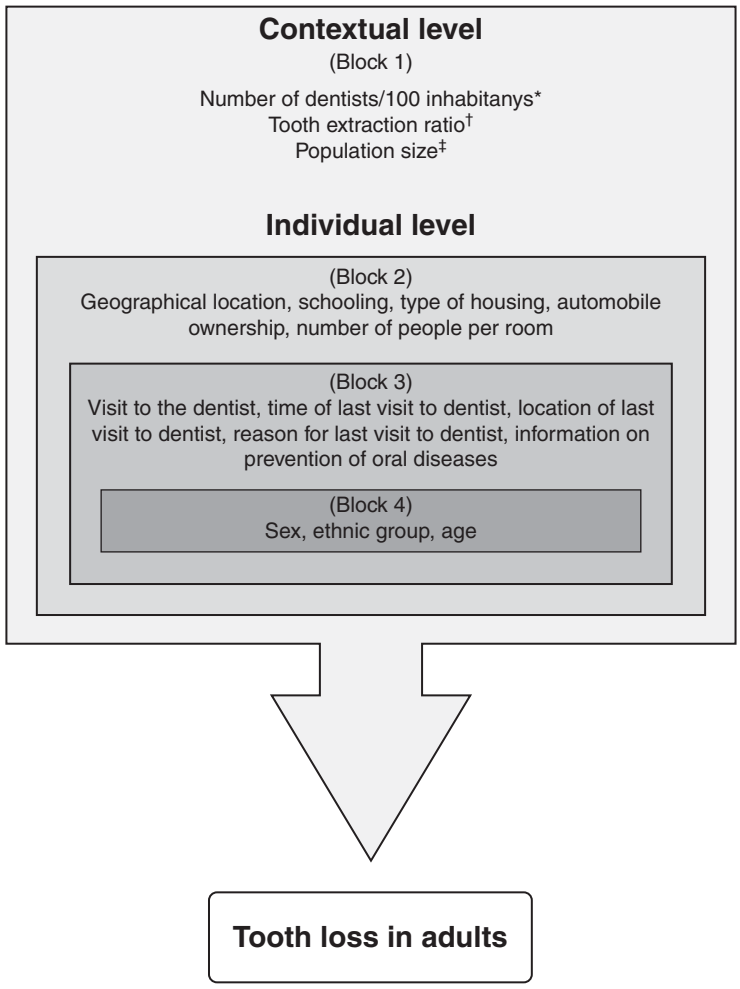

Figure 2. Theoretical–hierarchical model for tooth loss in adults. *Regional level. †State level. ‡Municipal level.

blocks. Ethnicity, however, was not a significant factor and did not remain in the final model.

Inter-level interactions were tested and revealed important aspects of the evaluation of effects. Figure 3 shows that the highest ratio of tooth extraction interacted with individuals who received information on the prevention of oral diseases and who had ≥9 years of schooling, changing the protective effect of these two variables. The interaction between individuals who had already been to the dentist and who had ≥2 automobiles significantly changed the risk associated with the first variable alone.

Discussion

The study of the social determinants of tooth loss is a complex and disputed issue. This is mainly due to the different predictive variables used in the literature. Gilbert et al. [16] studied the influence of race and socioeconomic conditions (SEC) on the incidence of tooth loss in adults in Florida. The authors suggested that the social determinants of tooth loss may work in opposite directions. As the only way of experiencing tooth loss is through entry into the dental care system (with the exception of small self-extractions), African–American individuals and people with low SEC would have less risk of tooth loss because they have less chance of entering the system. However, once they have gained access to the system, they will have an increased risk. The authors demonstrated that race and SEC lose their significance in the presence of dental diseases and symptoms, but they begin to have an effect again when the analysis is limited to individuals who had at least one visit to the dentist during the period under study. The authors suggest that these social differences in tooth loss are also manifested in the use of dental services and that disadvantaged individuals are given fewer treatment alternatives in cases where tooth extraction is one option.

In the present study, this may explain the risk of tooth loss found in people who have been to the dentist, as has also been found in Korean adults [17]. However, as most individuals in our study had gone to the dentist at least once in their life (97%), mainly in the public sector, social differences in access to the dentist could not be identified. The unequal

Table I. The mean number of teeth lost, standard deviation (SD), median and inter-quartile range (IQR) for 35–44-year-old Brazilians in 2003 according to category of predictor variable.

Variable	*N* (%)	Mean	SD	Median	IQR
No. of dentists/1000 inhabitants					
Up to the median (≤0.98)	9045 (67)	14.6	9.4	13	7–22
Above the median (>0.98)	4386 (33)	12.9	9.7	10	5–21
Tooth extraction ratio					
Tertile 1 (1.7–4.6)	5464 (40)	12.8	9.4	10	5–20
Tertile 2 (4.7–5.8)	4104 (30)	15.0	9.6	13	7–23
Tertile 3 (5.9–9.0)	3863 (30)	14.7	9.3	13	7–22
Population size					
≤100 000 inhabitants	10 373 (77)	14.5	9.6	12	6–22
>100 000 inhabitants	3058 (23)	12.5	9.0	10	5–19
Geographical location					
Urban	11 853 (88)	13.9	9.5	11	6–22
Rural	1569 (12)	15.3	9.5	14	7–23
Schooling (284*)					
None	1001 (7)	16.3	10.2	15	8–24
1–4 years	4602 (34)	16.2	9.6	15	8–24
5–8 years	4033 (30)	14.0	9.3	12	6–22
≥9 years	3511 (26)	10.9	8.5	8	4–15
Type of housing (64*)					
Own home	10 895 (81)	14.1	9.5	12	6–22
Not own home	2472 (18)	13.6	9.5	11	6–22
Car ownership (69*)					
0	9795 (73)	14.8	9.5	13	7-2-3
1	3212 (24)	12.2	9.2	9	5–20
≥2	355 (3)	9.9	8.5	7	4–13
People per room					
Up to the median (≤0.80)	7513 (56)	13.4	9.5	11	5–21
Above the median (>0.80)	5918 (44)	14.8	9.4	13	7–23
Visit to the dentist (49*)					
Have never been to the dentist	378 (3)	10.0	9.3	7	2–15
Have been to the dentist	13 004 (97)	14.2	9.5	12	6–22
Time of the last visit to dentist (484*)					
<1 year	5043 (37)	12.0	8.4	10	5–18
1–2 years	3002 (22)	13.2	8.9	11	6–21
≥3 years	4902 (36)	16.9	10.1	16	8–25
Location of last visit to dentist (453*)					
Private service	5993 (45)	13.0	9.4	10	5–21
Public service	6432 (48)	15.1	9.4	14	7–23
Other services	553 (4)	15.5	9.9	14	7–24
Reasons for last visit to dentist (426*)					
Routine	3516 (26)	11.0	8.5	8	4–16
Pain	6094 (45)	15.5	9.6	14	7–23
Cavities in the teeth	2113 (16)	13.8	8.9	12	7–21
Bleeding gums, swollen face or mouth injuries	1282 (10)	17.1	10.1	17	8–25

Table I. (*Continued*).

Variable	*N* (%)	Mean	SD	Median	IQR
Information on prevention of oral diseases (55*)					
Received information	7398 (55)	13.2	9.3	11	5–21
Did not receive information	5978 (45)	15.1	9.6	13	7–23
Sex					
Female	9078 (67)	15.1	9.7	13	7–23
Male	4353 (33)	11.8	8.6	9	5–17
Ethnic group (33*)					
Other	7505 (56)	14.5	9.3	13	7–22
Caucasian	5893 (44)	13.5	9.6	11	5–22
Age					
Up to the median (≤39 years)	7284 (54)	12.1	8.8	10	5–19
Above the median (>39 years)	6147 (46)	16.3	9.7	15	8–24
Total	13 431 (100)	14.0	9.5	12	6–22

*Missing data.

male and female distribution of participants may also explain this phenomenon, considering that women seek health services more frequently than men. Similarly, ethnicity had no effect on tooth loss when adjusted for variables from the higher blocks (final model). This suggests that the presence of ethnicity as a risk marker in some communities may be due to some confounding factor. However, other studies have confirmed a higher risk of tooth loss among African–American individuals [9,11,12].

The test of interactions (Figure 3) showed significant relationships between contextual and individual variables. The interactions suggest that even individuals with higher education or receiving information on prevention had an increased risk when living in states with a high ratio of tooth extraction. This result shows the influence of a contextual variable relating to the dental service on the effect of individual factors, independent of other variables adjusted in the final model. Thus, someone who has visited a dentist but has ≥2 cars showed a decrease of 64% in the risk of tooth loss. This finding provides evidence that, depending on the socioeconomic level, going to the dentist may represent either a risk of, or protection against, tooth loss.

Dental variables, such as the presence of caries and periodontal disease, are the main predictors of tooth loss [8–12]. The presence of bleeding as the reason for the last visit to the dentist showed a high risk for tooth loss (MR = 1.387). This condition is an important marker of periodontal disease which, along with dental caries, represents an important predictor of tooth loss in adults and the elderly.

The absence of longitudinal studies providing details of the reasons for the extraction leaves room for two hypotheses, according to Gilbert et al. [9]: on the one hand, people first decided to remove a tooth as a result of a specific problem and went to the dentist as a consequence, while, on the other hand, they first decided to seek out a dentist owing to a specific problem and went to the dentist to see what could be done. In the first case, the symptoms and specific problems determined the tooth loss. In the second case, the dental care determined the outcome. Oral problems and dental symptoms would have a direct effect on the use of dental services and an indirect effect on tooth loss.

A point which may seem paradoxical is the protective effect in regions that have a higher number of dentists/1000 inhabitants. Despite the fact of having attended a dentist being a risk factor, this risk may be explained by the reason given above. The larger number of dentists, besides possibly reflecting better infrastructure and urban development in the region (regions with a higher degree of urbanization tend to have a greater supply of human resources), also implies a wider range of alternative forms of dental treatment, more regular access and the provision of preventive procedures. It should be emphasized that the risk for those who visited the dentist 1–2 years previously was much smaller compared to that for those who last went ≥3 years previously. Likewise, larger cities (with >100 000 inhabitants) revealed a protective effect against tooth loss.

In a large number of the studies reviewed, a low level of education and low income were important predictors of tooth loss [10,18–21]. Individuals with little schooling and poor socioeconomic conditions experience high incidences of oral diseases and tooth loss and tend to visit a dentist only when they feel they have a problem, and not for routine visits. On the other hand, wealthy individuals and those with more

Table II. Adjusted MR for tooth loss among 35–44-year-old Brazilians in 2003 according to category of predictor variable.

	Regression coefficient	Standard error	MR	95% CI	*P*
Variables at the contextual level (Block 1)*					
Regional level					
No. of dentists/1000 inhabitants					
Up to the median (≤0.98)			1.000		
Above the median (>0.98)	–0.093	0.032	0.911	0.856–0.970	0.0039
State level					
Ratio of tooth extraction					
Tertile 1 (1.7–4.6)			1.000		
Tertile 2 (4.7–5.8)	0.068	0.037	1.070	0.995–1.151	0.0672
Tertile 3 (5.9–9.0)	0.126	0.038	1.134	1.053–1.222	0.0008
Municipal level					
Population size					
≤100 000 inhabitants			1.000		
>100 000 inhabitants	–0.136	0.032	0.873	0.820–0.929	<0.0001
Variables at the individual level (Block 2)†			1.000		
Schooling					
None					
1–4 years	0.018	0.023	1.018	0.973–1.065	0.4443
5–8 years	–0.075	0.024	0.928	0.885–0.972	0.0019
≥9 years	–0.324	0.025	0.723	0.689–0.760	<0.0001
Car ownership					
0			1.000		
1	–0.098	0.015	0.907	0.880–0.934	<0.0001
≥2	–0.271	0.040	0.763	0.705–0.825	<0.0001
Variables at the individual level (Block 3)‡					
Visit to the dentist					
Have never been to the dentist			1.000		
Have been to the dentist	0.289	0.040	1.335	1.234–1.444	<0.0001
Time of last dental visit					
<1 year			1.000		
1–2 years	0.034	0.015	1.035	1.005–1.065	0.0269
≥3 years	0.193	0.014	1.213	1.180–1.247	<0.0001
Reasons for last dental visit					
Routine			1.000		
Pain	0.149	0.016	1.161	1.125–1.198	<0.0001
Cavities in the teeth	0.098	0.019	1.103	1.063–1.145	<0.0001
Gingival bleeding, swollen face or wounds in the mouth	0.327	0.022	1.387	1.328–1.448	<0.0001
Information on prevention					
Did not receive information			1.000		
Received information	–0.057	0.012	0.945	0.923–0.967	<0.0001
Variables at the individual level (Block 4)§					
Sex					
Male			1.000		
Female	0.243	0.012	1.275	1.245–1.305	<0.0001

Table II. (*Continued*).

	Regression coefficient	Standard error	MR	95% CI	*P*
Age					
Up to the median (≤39 years)			1.000		
Above the median (>39 years)	0.279	0.011	1.322	1.294–1.351	<0.0001

*Adjusted for the contextual variables (block 1).
†Adjusted for the contextual variables and for block 2.
‡Adjusted for the contextual variables and for blocks 2 and 3.
§Adjusted for the contextual variables and for blocks 2–4.

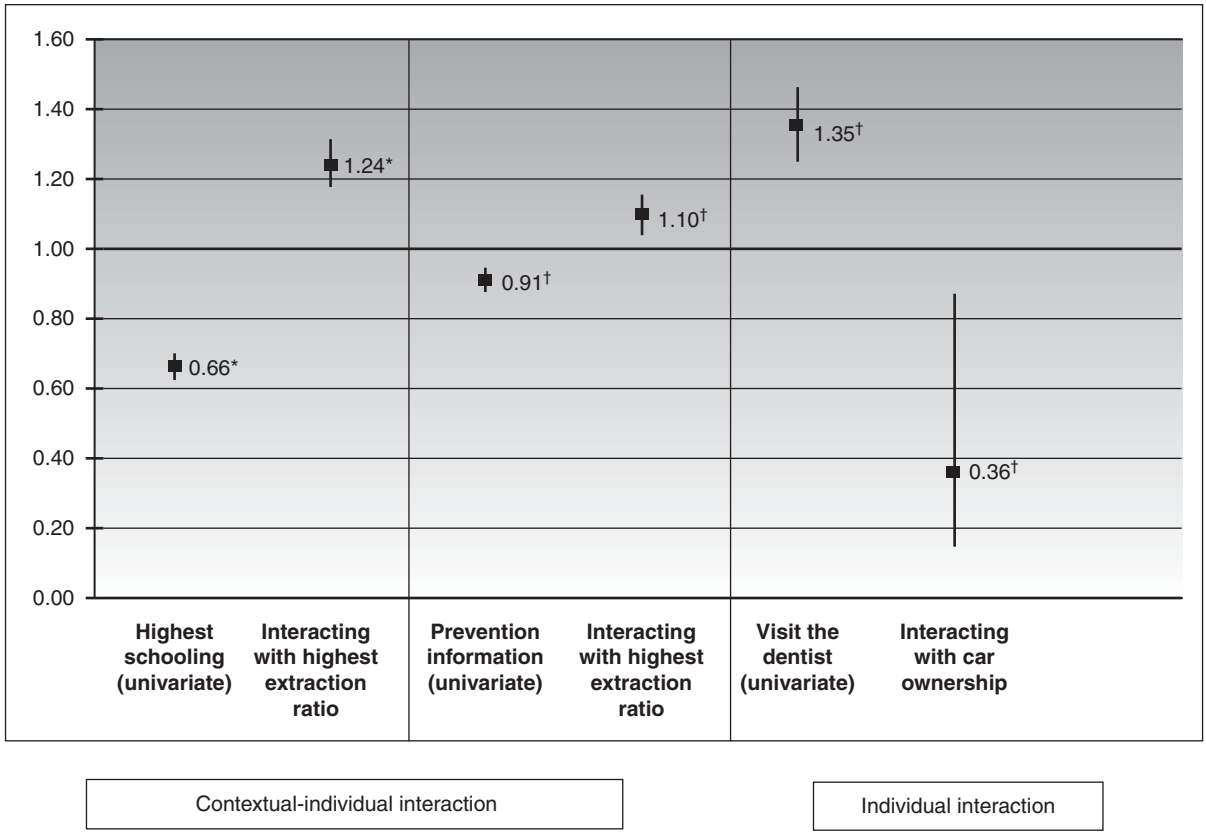

Figure 3. MR and 95% confidence intervals for contextual and individual variables presenting interactions. *MR adjusted for the contextual variables and for the remaining variables in block 2. †MR adjusted for the contextual variables and for the remaining variables in blocks 2 and 3.

schooling have a lower incidence of tooth loss and visit the dentist more often and for routine check-ups [18,19].

The female individuals presented an elevated risk of tooth loss. This finding confirms results found in several studies [9,10,19,22]. However, this is controversial and some studies have concluded that sex is not a significant predictor of tooth loss [8,21,23] or that men are more at risk [17,20]. Such divergences may reflect a gender difference rather than one of sex, which therefore will involve more cultural aspects (lifestyle, use of health services, etc.) and fewer biological ones.

The present study has a number of limitations. Although the multilevel model was corrected for the clustering effect (as represented by the dependence of individuals on the sample levels) and generated more accurate estimates of standard errors by partitioning variances, the epidemiological survey used does not provide information on the rate of non-response, hampering both the definition of sample weights for descriptive analysis and the verification of potential bias arising from a refusal to cooperate. Another aspect is that the present study examined tooth loss in all individuals, including those who have lost all their teeth (edentulous). Although this

strategy avoids cutoff points and provides a pluralistic approach to tooth loss, Copeland et al. [8] suggest the presence of different predictors for tooth loss and edentulism. Future approaches must consider this possibility in a longitudinal situation. Another point is that the dependent variable was number of lost teeth from 0 to 32. This approach was chosen with a view to identifying the factors related to tooth loss, although it is known that not all individuals had 32 teeth to start with.

It must also be stressed that the effects of contextual variables should not be interpreted as individual attributes (in view of the existence of the ecological fallacy or simply the cluster effect), but as sociogeographical characteristics of the environment of the respondents. It is thus plausible that the contextual variables investigated here do not apply to the reality of each individual alone, but represent the powerful effect of the context on all the individual results.

In conclusion, this study highlights the important role of contextual aspects in individual exposure profiles. The risk factors involved in this phenomenon had effects at multiple levels, in accordance with theoretical references regarding the determination of health and disease. While understanding the effect of the contextual level on oral health is important, it takes time to change dental treatment philosophy from favoring extraction to promoting prevention and restoration.

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