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INFLUENCE OF COMMUNITY WATER FLUORIDATION ON THE PERIODONTAL STATUS OF BRAZILIAN ADULTS: A CROSS-SECTIONAL STUDY

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Guilherme Nunes de CARVALHO[1], Jean Nunes dos SANTOS[2], Daniel Araki RIBEIRO[3], Patrícia Ramos CURY[4*]

[1] Postgraduate Program in Dentistry and Health, School of Dentistry, Federal University of Bahia, Salvador, Brazil.
[2] Associate Professor, Department of Oral Pathology, School of Dentistry, Federal University of Bahia, Salvador, Brazil.
[3] Associate Professor, Department of Biosciences, Federal University of São Paulo, Santos, Brazil.
[4] Associate Professor, Department of Periodontics, School of Dentistry, Federal University of Bahia, Salvador, Brazil.

***Corresponding author:**
Dr. Patrícia Ramos Cury
Department of Periodontics
School of Dentistry, Federal University of Bahia
Av. Araújo Pinho, 62, Canela
40110-150, Salvador (Bahia), Brazil
Phone: (+55)71-981410188
E-mail: patcury@yahoo.com.br

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ABSTRACT

Purpose: Community water fluoridation is a widely implemented measure because of its benefits in preventing tooth decay. However, the effects of fluoride on the periodontium remain unclear, as the reported results are contradictory. The aim of this study was to evaluate whether an association exists between fluoridated water consumption and periodontal status in Brazil, adjusting for potential confounding factors.

Methods: Using data from 21,543 adults residing in 250 Brazilian cities collected through a national oral health survey, we applied multinomial logistic regression to examine the association between the duration of community water fluoridation and periodontal status measured by the Community Periodontal Index.

Results: There was a 1.012 times increase (95% CI 1.006-1.019) in the odds of having periodontitis for each year of water fluoridation after adjusting for age, household income, education level, and sex for the whole country, as well as a 1.023 (95% CI 1.010-1.036) and 1.029 times (95% CI 1.018-1.039) increase in the Southeast and South regions, respectively. No significant association was found with gingivitis in the national scenario. In the North region, there was a decrease (OR 0.943, 95% CI 0.907-0.981) in the odds of developing gingivitis for each year of water fluoridation, while an increase was found in the Southeast (OR 1.017, 95% CI 1.009-1.025) and South (OR 1.023, 95% CI 1.017-1.030) regions.

Conclusions: Community water fluoridation appears to increase the risk of periodontal disease, particularly in Brazilian regions with higher water fluoridation levels. These findings highlight the importance of a balanced approach to public health interventions, ensuring that benefits outweigh potential risks.

Key-words: *Community water fluoridation; Periodontal health; Periodontitis; Gingivitis; Probing depth*

INTRODUCTION

The benefits of fluoridated water consumption in reducing the frequency of cavities and tooth loss are well-documented.[1] Consequently, many regions worldwide have adopted community water fluoridation as part of their public health policies.[1]

On the other hand, the effects of consuming fluoridated water on periodontal health remain uncertain as research is limited and the findings are conflicting.[2] *In vitro* studies have suggested a potential interaction between fluoride and the periodontium. Krook et al.[3] demonstrated alveolar bone necrosis in a cattle herd with dental fluorosis. Studies have also shown that sodium fluoride at concentrations of 150 mg/L or higher is cytotoxic to human gingival epithelial cell cultures and oral mucosa fibroblasts, causing apoptosis.[4,5] However, such concentrations are not found in drinking water intended for human consumption[6] Furthermore, an electron microscopy analysis of healthy teeth extracted for orthodontic reasons, both with and without fluorosis, revealed larger numbers of hypermineralized surfaces, mineralized periodontal ligament fibers, and calculus-related structures in the fluorosis group.[7] These findings highlight the urgency of investigating whether fluoride added to public water supplies could pose risks to periodontal health, especially considering its widespread use as a public health measure.

Epidemiological studies on this topic are inconclusive. A recent study comparing populations from areas with and without fluoridated water across different age groups found lower probing depths, clinical attachment loss, and gingival inflammation in the population with access to fluoridated water.[8] Another study also reported a higher risk of periodontitis among adults from areas with low fluoridation compared to those from highly fluoridated areas.[9] Conversely, a study on adolescents and adults with fluorosis showed a higher frequency of periodontitis in the group with a higher degree of fluorosis.[10] Similarly, a prevalence of gingivitis of 97% has been reported among children from a high-fluoridation area in Ethiopia.[11] However, some studies comparing high and low fluoridation areas found no influence of fluoride on periodontal inflammation.[12,13]

The conflicting results of these studies impair the elucidation of the effects of fluoride on the periodontium. Moreover, the cited studies exhibit methodological discrepancies, often lack a control group not exposed to fluoridated water, and fail to thoroughly explore other factors that influence periodontal inflammation. Given the importance of elucidating the complex relationship between fluoridated water and periodontal health, this study aimed to investigate whether an association exists between the duration of fluoridated water consumption and periodontal status in Brazil, adjusting for potential confounding factors. The study hypothesizes that the duration of fluoridated water consumption is associated with periodontal diseases.

MATERIAL AND METHODS

Study design

This is a cross-sectional study that used the database from the national oral health epidemiological survey, SB Brasil[14], a household-based survey involving a representative sample of individuals across Brazil. The data comprised information from individuals in 250 cities across the five macro-regions of the country: North, Northeast, Southeast, South, and Center-West.

Participants

The study included data from 21,543 individuals aged 18 years or older residing in urban areas.

Data collection

The database used is available on the official website of the Ministry of Health. Briefly, data were collected in each household by a team consisting of a dental examiner and an annotator. This study used data from individuals in the following age ranges: 35 to 44 years and 65 to 74 years. Socioeconomic information was collected through interviews and oral health conditions were assessed by periodontal probing. Additionally, after visiting the households, information systems were consulted to determine whether the residences received fluoridated water and, if so, for how long. Oral examinations were conducted under natural light, with the participant properly positioned for each examination. The Community Periodontal Index (CPI) was used for periodontal assessment. The index teeth (17/16, 11, 26/27, 36/37, 31, 47/46) in each sextant that contained two or more teeth not indicated for extraction were examined. The condition of each sextant was classified based on the worst observed state as one of the

following: healthy, bleeding on probing, presence of visible calculus, pocket depth of 4–5 mm, or pocket depth of 6 mm or greater. Additionally, the extent of clinical attachment loss (CAL) was assessed and categorized as 0-3, 4-5, 6-8, 9-11, and 12 mm or more.

Variables and categorization

The outcomes used in this study were the maximum CPI identified in each individual, indicating periodontal status, and the CAL score, indicating the extent of periodontal disease. For the maximum CPI, bleeding on probing and the presence of visible calculus were considered indicative of gingivitis, while pocket depths of 4-5 and 6 mm or more were considered indicative of periodontitis. Thus, the maximum CPI was recategorized into three categories: healthy periodontium, gingivitis, or periodontitis. For CAL, four categories were created: minimal attachment loss (0-3 mm), low loss (4-5 mm), moderate loss (6-8 mm), and severe loss (9 mm or more).

The duration of fluoridated water supply in years (continuous variable) was the independent exposure variable. Covariates included age in years (continuous variable), sex (dichotomous variable; male or female), household income (categorical variable; low income: up to 1 minimum wage (corresponding to US$ 290.00 at the time of the study), medium income: 1-2 minimum wages, high income: > 2 minimum wages), and education level in years of schooling (continuous variable).

Data analysis

Multinomial logistic regression was used to estimate the odds ratios (OR) for the association between periodontal status and duration of exposure to fluoridated water, adjusted for age, sex, household income, and education level. Analyses were conducted for the whole country and separately for each macro-region. Whenever there was an association between periodontitis and the duration of fluoridated water exposure, multinomial regression was also performed for CAL. The proportional odds assumption test was invalid for our models and we therefore used multinomial logistic regression instead of ordinal logistic regression. Independent variables were tested for multicollinearity using the variance inflation factor (VIF), and the models were constructed after a negative result. Variables were selected and included in the regression model using a stepwise forward method, adding significant variables in order of significance. The absence of the duration of exposure to fluoridated water in the final model indicated a lack of significant association.

Analyses were conducted using the SPSS 26.0 software. A 95% confidence interval (CI) was applied in the tests and a *p*-value ≤0.05 was considered significant.

RESULTS

Data from 21,543 individuals across the five macro-regions of Brazil were analyzed. The mean age was 40.79 years, with a mean of 5.95 years of schooling and 8.49 years of water fluoridation. The majority of individuals across all macro-regions were female (>63%). The household income was predominantly low in the North and Northeast and high in the Southeast, South, and Center-West. Additionally, most individuals had gingivitis (Table 1).

In the logistic regression analyses, high income served as the reference for household income and male sex as a reference for sex. For the continuous variables – duration of exposure to fluoridated water, age, and education level – each additional year increased or decreased the odds of the outcome by a factor equal to the corresponding OR for that variable.

Association between fluoridated water and periodontal status

Brazil

At the national level, logistic regression revealed that a longer duration of exposure to fluoridated water was associated with a higher chance of having periodontitis (OR 1.012, 95% CI 1.006-1.017), after adjusting for age, household income, education level, and sex. There was no significant association between the duration of fluoridated water exposure and gingivitis. Older age, a lower household income, and male sex were associated with a higher chance of having both gingivitis and periodontitis. Conversely, higher education level decreased the chances of both gingivitis and periodontitis (Table 2).

Table 1. Characteristics of individuals included in the study.

	Brazil		North		Northeast		Southeast		South		Center-West	
	n (%)	M (SD)	n (%)	M (SD)	n (%)	M (SD)	n (%)	M (SD)	n (%)	M (SD)	n (%)	M (SD)
Age	21,543	41 (17)	4,172	38 (16)	5,343	41 (17)	3,680	42 (18)	5,070	42 (17)	3,278	40 (17)
Female	64.9%	-	64.7%	-	66.3%	-	65.0%	-	63.3%	-	65.6%	-
Male	35.1%	-	35.3%	-	33.7%	-	35.0%	-	36.7%	-	34.4%	-
Household income low	30.1%	-	38.5%	-	44.7%	-	24.1%	-	15.8%	-	24.9%	-
Household income medium	26.6%	-	31.0%	-	27.8%	-	25.9%	-	23.2%	-	25.1%	-
Household income high	43.3%	-	30.6%	-	27.4%	-	50.1%	-	61.0%	-	50.0%	-
Education level (years)	20,148	5.95 (4.17)	3,933	55.59 (4.11)	4,937	5.57 (4.23)	3,483	6.05 (4.16)	4,788	6.46 (4.03)	3,007	6.14 (4.29)
Duration of fluoridation (years)	21,405	8.49 (10.96)	4,172	0.61 (1.94)	5,205	2.10 (4.83)	3,680	11.7 (10.97)	5,070	19.80 (11.54)	3,278	7.59 (7.43)
With water fluoridation	10,782 (50.1)	-	397 (9.5)	-	1,137 (21.3)	-	2,516 (68.4)	-	4,664 (92.0)	-	2,068 (63.1)	-
Without water fluoridation	10,761 (49.9)	-	3,775 (90.5)	-	4,206 (78.7)	-	1,164 (31.6)	-	406 (8.0)	-	1,210 (36.9)	-
Periodontal status:												
Healthy	5,317 (30.5)	-	899 (25.6)	-	1,079 (24.9)	-	1,017 (35.6)	-	1,383 (33.9)	-	939 (35.7)	-
Gingivitis	10,555 (60.6)	-	2,296 (65.4)	-	2,891 (66.6)	-	1,560 (54.6)	-	2,299 (56.4)	-	1,509 (57.4)	-
Periodontitis	1,537 (8.8)	-	314 (8.9)	-	369 (8.5)	-	280 (9.8)	-	395 (9.7)	-	179 (6.8)	-

n: Sample number %: Percentage; M: Mean; SD: Standard deviation.

Table 2. Logistic regression of the influence of water fluoridation on periodontal status in Brazil (n=15,866).

	Gingivitis		Periodontitis	
	OR	**95% CI**	**OR**	**95% CI**
Age	1.020*	1.017-1.023	1.044*	1.039-1.048
Household income				
Low	1.411*	1.285-1.549	1.593*	1.360-1.867
Medium	1.267*	1.156-1.388	1.382*	1.180-1.618
High (reference)				
Education level	0.937*	0.928-0.947	0.910*	0.894-0.926
Sex				
Male	1.229*	1.140-1.324	1.443*	1.274-1.636
Female (reference)				
Water fluoridation	1.001^{ns}	0.998-1.005	1.012*	1.006-1.017

*: p<=0.05; ^{ns}: p>0.05; OR: Odds ratio; 95% CI: 95% Confidence interval.

South

The results showed that the longer the duration of exposure to fluoridated water, the higher the chances of having both gingivitis (OR 1.023, 95% CI 1.017-1.030) and periodontitis (OR 1.029, 95% CI 1.018-1.039), after adjusting for age, education level and sex. Older age was associated with higher chances of both gingivitis and periodontitis, and male sex increased the chance of having gingivitis, while a higher education level decreased the chances of having the two conditions.

Southeast

The results revealed that the longer the duration of exposure to fluoridated water, the higher the chances of having both gingivitis (OR 1.017, 95% CI 1.009-1.025) and periodontitis (OR 1.023, 95% CI 1.010-1.036), after adjusting for age, household income, and education level. Older age and a lower household income were associated with higher chances of both gingivitis and periodontitis, while a higher education level decreased the chances of having the two conditions.

North

In the North region, the results revealed that the longer the duration of exposure to fluoridated water, the lower the chance of having gingivitis (OR 0.943, 95% CI 0.907-0.981), after adjusting for age, household income, education level, and sex. The duration of exposure to fluoridated water was not significantly associated with periodontitis. Older age and a lower household income were associated with higher chances of both gingivitis and periodontitis, while male sex increased the chance of having periodontitis. A higher education level decreased the chances of both gingivitis and periodontitis.

Northeast and Center-West

In the Northeast and Center-West regions, the final logistic regression model did not include the duration of exposure to fluoridated water, indicating the lack of association with periodontal status.

Association between fluoridated water and periodontal attachment loss

Multinomial logistic regressions were performed to estimate the OR between periodontal attachment loss and the duration of exposure to fluoridated water at the national level and in the Southeast and South macro-regions since an association between exposure to fluoridated water and periodontitis was observed in these regions.

Brazil

Nationally, logistic regression revealed that the longer the duration of exposure to fluoridated water, the higher the chance of low (OR 1.010, 95% CI 1.006-1.014), moderate (OR 1.013, 95% CI 1.007-1.019), and severe attachment loss (OR 1.009, 95% CI 1.001-1.018), after adjusting for age, household income, education level and sex. Older age, a lower household income, and male sex were associated with higher chances of low, moderate, and severe attachment loss, while a higher education level decreased the chances of all extents of attachment loss.

Southeast

In the Southeast region, the final logistic regression model did not include the duration of exposure to fluoridated water, indicating the lack of association with the extent of periodontal attachment loss.

South

In the South region, the results showed that the longer the duration of exposure to fluoridated water, the higher the chance of low (OR 1.017, 95% CI 1.009-1.025) and moderate attachment loss (OR 1.024, 95% CI 1.012-1.035), after adjusting for age, household income, education level and sex. The duration of exposure to fluoridated water was not significantly associated with severe attachment loss. Older age and male sex were associated with higher chances of low, moderate, and severe attachment loss, while a lower household income increased the chance of severe attachment loss. A higher education level decreased the chances of moderate and severe attachment loss.

DISCUSSION

This cross-sectional study investigated the relationship between the duration of fluoridated water consumption and periodontal status in Brazilian adults, adjusting for age, household income, education level, and sex. To our knowledge, this is the first study to include a control group of individuals not exposed to fluoridated water while accounting for other factors that influence periodontal status. Longer fluoridated water consumption was associated with an increased risk of periodontitis in the South and Southeast Brazilian regions and considering data for the whole country. Additionally, the duration of exposure to fluoridated water was associated with low and moderate periodontal attachment loss in the whole country and in the South region. Therefore, the findings of this study confirmed the hypothesis that the duration of fluoridated water consumption is associated with periodontal diseases.

In the present population, the odds of developing disease increased with longer exposure to fluoridated water in the whole Brazilian population and in the regions with the highest fluoridation rates, South and Southeast. Similarly, a study comparing individuals with and without fluorosis reported a significantly higher prevalence of periodontitis among those with fluorosis,[10,15] with an increase in the frequency of periodontitis according to the severity of the condition.[15] Conversely, a study that compared individuals from fluoridated and non-fluoridated areas found a mean decrease of 0.5 mm in probing depth and of 0.3 mm in attachment loss in non-fluoridated areas, a small variation that is within the standard deviation range.[8] In another study involving populations from areas with different fluoride concentrations in water, the severity of periodontal disease was inversely proportional to fluoride concentration.[9] However, these studies did not compare groups of individuals with and without access to fluoridated water nor did they consider other factors influencing periodontal disease, an important fact given the multifactorial nature of the disease.

Contrary to the national findings, fluoridated water appears to act as a protective factor against gingivitis in the North of the country. This discrepancy might be attributed to unequal sample sizes between the exposed and non-exposed groups, with only 9% of individuals in the region having access to fluoridated water.

This study did not find an association between fluoridated water consumption and gingivitis in the national scenario. This finding might be explained by the lack of information on the presence or absence of

gingivitis in each individual in the database and the fact that the CPI may have underestimated gingivitis in this population. A study of children from areas with different water fluoride concentrations found that the highest Simplified Oral Hygiene Index scores were associated with high fluoride levels.[16] Furthermore, a high prevalence of gingivitis has been observed among populations living in regions with fluoridated water.[11,17]

The influence of fluoride in drinking water on periodontitis may be attributed to its potential toxicity, with fluoride having an early effect on the periodontium by altering its formation or by exerting proinflammatory activity, or through a combination of the two mechanisms. Generally, high doses of fluoride trigger oxidative stress, disrupt the cell cycle, and induce apoptosis.[18] Although the exact mechanism of fluoride toxicity is not fully understood, it is believed to involve protein inhibition, organelle destruction, pH alteration, and electrolyte imbalance.[18] Within this context, the average microhardness of cementum tends to be lower in teeth with fluorosis compared to teeth without fluorosis.[19] Moreover, higher concentrations of biomarkers of tissue destruction, such as chondroitin sulfate and sialic acid, are found in the crevicular fluid of individuals with both periodontitis and fluorosis compared to those with periodontitis alone.[20] Additionally, sodium fluoride, even at low concentrations, has been shown to induce an inflammatory response and promote apoptosis in macrophages by stimulating prostanoid metabolism and increasing the synthesis of prostaglandin E2 and thromboxane A2.[21]

Regardless of water fluoridation, studies indicate that the decline in cavity rates and lower average tooth loss have been global trends over recent years.[22,23] This trend may be associated with the widespread use of fluoridated toothpaste.[24-26] Nevertheless, recent cohort studies conducted in the UK and England found that optimal water fluoridation had very small effects on dental caries and tooth loss, and there was no evidence of a reduction in social inequalities.[27,28] Therefore, the possible revision of current fluoridation policies must be discussed. This measure is implemented worldwide and our results indicate that it may have a negative impact on periodontal health.

As a limitation, the periodontal health data were collected for index teeth because of the large sample size of the national survey; thus, complete assessment of all teeth could increase the reliability of the results. Additionally, although we adjusted for several confounding factors, other missing information in the survey, such as the presence of diabetes, smoking habits, and plaque levels, should be considered. Generalization of the results should also be done with caution since they may represent the specific context of Brazil.

Future research should focus on longitudinal studies to elucidate the temporal relationship between water fluoridation and periodontitis. Experimental studies are also needed to investigate the underlying biological mechanisms. Additionally, investigations involving different geographical and cultural contexts should be encouraged since they may help determine if the present findings apply to other populations.

CONCLUSIONS

The findings of this study suggest that community water fluoridation may be associated with an increased risk of periodontitis in Brazil. These results highlight the need for a reevaluation of water fluoridation policies, considering their potential impact on periodontal health.

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CONFLICT OF INTERESTS

None.

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