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A 15-Year Time-series Study of Tooth Extraction in Brazil

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Abstract: Tooth loss is considered to be a public health problem. Time-series studies that assess the influence of social conditions and access to health services on tooth loss are scarce.

This study aimed to examine the time-series of permanent tooth extraction in Brazil between 1998 and 2012 and to compare these series in municipalities with different Human Development Index (HDI) scores and with different access to distinct primary and secondary care.

The time-series study was performed between 1998 and 2012, using data from the Brazilian National Health Information System. Time-series study was performed between 1998 and 2012. Two annual rates of tooth extraction were calculated and evaluated separately according to 3 parameters: the HDI, the presence of a Dental Specialty Center, and coverage by Oral Health Teams. The time-series was analyzed using a linear regression model.

An overall decrease in the tooth-loss tendencies during this period was observed, particularly in the tooth-extraction rate during primary care procedures. In the municipalities with an HDI that was lower than the median, the average tooth-loss rates were higher than in the municipalities with a higher HDI. The municipalities with lower rates of Oral Health Team coverage also showed lower extraction rates than the municipalities with higher coverage rates.

In general, Brazil has shown a decrease in the trend to extract permanent teeth during these 15 years. Increased human development and access to dental services have influenced tooth-extraction rates.

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Abbreviations: HDI = Human Development Index, SUS = Brazilian Health System.

INTRODUCTION

Oral health care is part of general health, and it is currently considered to be essential to an individual's quality of life.[1] Therefore, tooth loss is considered to be one of the worst health problems resulting from oral diseases. This condition results in decreased functional capacities for chewing and speech, and nutritional, psychological, and aesthetic damage, in addition to problems with social relations. In Brazil, the tooth loss via tooth extractions caused by preventable diseases, including dental caries and periodontal diseases, is very high. The prevalence of any tooth loss (15–19-y-old), presence of less than 21 natural teeth (35–44-y-old), and edentulism (65–74-y-old) were, respectively, equal to 17.4% (95% confidence interval [CI] 14.7; 20.4), 22.4% (95% CI 19.9; 25.2), and 53.7% (95% CI 49.8; 57.6) in 2010 in Brazil.[2] The actions to control these diseases and the important impact on the lives of the affected individuals are challenges to public health to minimize this problem.[3]

Earlier studies[4–8] found that the level of education, place of residence, occupation, nutritional status, income, and access to dental care are associated with tooth loss. However, time-series studies assessing the influence of these factors on tooth loss are scarce.

In this respect, we observed and described the trend to extract permanent teeth in the past 15 years as a way of assessing whether there were changes in the healthcare model and as a means of supporting the planning, monitoring, and evaluation of the National Oral Health Policy in Brazil. Therefore, the aim of the study was to describe the time-series of permanent tooth extraction in Brazil between 1998 and 2012 and to compare these series in municipalities with different Human Development Index (HDI) scores, in municipalities with and without access to secondary care via Dental Specialty Centers and in municipalities with distinct organizational indicator of primary care (Oral Health Team coverage).

METHODS

Ethical Clearance

Ethical clearance was not required, as the data obtained from the Brazilian National Health Information System of the Ministry of Health were public, aggregated, and anonymous. Written consent was not obtained because the data were public and aggregated at the municipal level. Patient information was anonymized and de-identified before analysis.

Place of Study

A time-series study was held in Brazil, a country in South America, which has a land area of 8,514,876 square kilometers and a total population of approximately 203 million people.[9] It consists of 26 states and 1 federal district that include 5564 municipalities containing great diversity and socioeconomic inequality.

The Brazilian Health System is based on the constitutional principle that all citizens have the right of access to health care, and it is governed by the Brazilian Health System (SUS in Portuguese). In terms of primary care, the health care model adopted by the SUS is the Family Health Strategy. Dentistry has been included in the Family Health Strategy since 2000, and the National Oral Health Policy has incorporated secondary care via Dental Specialty Centers since 2004. At the primary level, the

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collective and individual actions on the territory/area of coverage are standard, in addition to preventive, surgical, and restorative dental procedures. The Dental Specialty Center primarily includes endodontics, periodontics, oral medicine, and oral surgery.[10]

Variables Analyzed

All of the analyzed data, including the outpatient treatment, presence of a Dental Specialty Center, and coverage by oral health teams [Oral Health Team] in the Family Health Strategy, were obtained from secondary and public sources from the Brazilian National Health Information System of the Ministry of Health. The HDI for 1998, 2003, and 2010 was proposed by the United Nations Development Programme,[11] and the HDI estimates and population counts from 1998 to 2012[9] were analyzed. HDI was presented in the 1990s by the United Nations Development Programme. The HDI combines 3 requirements for the life of people: the opportunity to lead a long and healthy life—health; to have access to knowledge—education; and finally to enjoy a decent standard of living—income.[11]

The data were extracted and exported in December 2013, and the tabulation was performed using Excel for Windows. The data were extracted from the health systems by a single researcher with 8 years of experience in these web environments. The database was evaluated for inconsistencies by a senior epidemiologist for quality control. The data from all 5564 Brazilian municipalities were analyzed.

All of the preventive, restorative, and surgical oral health procedures (permanent tooth extractions) in each of the Brazilian municipalities were recorded. The preventive procedures included the topical application of fluoride, sealant application, cariostatic application, and the control of dental plaque and supra and subgingival scaling. The restorative procedures included direct restorations of the permanent and primary teeth, direct pulp capping, and pulpotomies. The number of permanent-tooth extractions was also recorded for each Brazilian municipality. The extractions of primary teeth, impacted, or unerupted teeth were excluded. It was not possible to identify tooth extractions caused by dental trauma or orthodontic reason and the age of the population in the Brazilian National Health Information System of the Ministry of Health. Considering that SUS is a universal healthcare system, we probably evaluated tooth extraction among children, adolescents, adults, and the older patients.

Two extraction rates were calculated. The first is the ratio of the extractions of permanent teeth in relation to the total number of individual dental procedures that were performed (surgical, restorative, and preventive procedures).[12] The second is the ratio of the number of extractions of permanent teeth divided by the total population.[13]

The 2 rates were calculated separately based on 3 covariates: the HDI (high and low), the presence of a Dental Specialty Center (with and without), and the Oral Health Team coverage (high and low). According to the covariate, the extraction rates represent the mean of the rates for 2 subgroups of municipalities (high and low or with and without).

The 2 tooth-extraction rates were computing separately according to the median of the HDI. For the period between 1998 and 1999, the 1998 HDI was used (estimated from the census data from 1970, 1980, and 1991). For the period from 2000 to 2009, the 2003 HDI was used (estimated from the 2000 census data). Finally, for the period from 2010 to 2012, the 2010 HDI was used (estimated from the 2010 census data).[11]

The presence of a Dental Specialty Center was recorded dichotomously (with or without). The Oral Health Team coverage is calculated by adding up the total number of oral health teams (Oral Health Team) per year for each municipality and multiplying by 3450.[14,15] The result is then divided by the population for each respective year.

To compare the extraction rates between municipalities that had a Dental Specialty Center with those that did not, we analyzed the period from 2004 to 2012, as 2004 marked the beginning of the current National Oral Health Policy in Brazil.[10]

Both rates were also compared between municipalities with an Oral Health Teams less than or equal to the median or above the median for each of the years. We analyzed the period from 2000 to 2012, as 2000 marked the commencement of the implementation of Oral Health Teams in the Family Health Strategy in Brazil.[16]

So the 2 extraction rates for each year were calculated considering the 2 groups of municipalities (eg, one rate for those with a Dental Specialty Center and another for those without a Dental Specialty Center).

Statistical Methods

The statistical analysis of the time-series was performed using a linear regression model. This technique is used when you want to relate or explain a variable of interest (dependent) via other variables (independent or covariates). In other words, the model aims to find the regression equation that best describes the relationship between the independent variables (Y) and the dependent variable (Y). The multiple linear regression model is defined as follows[17]:

$$Y_t = X_t\boldsymbol{\beta} + \varepsilon_t \; \varepsilon_t \sim N(0, \sigma^2),$$

for $t = 1, \ldots, n$, where Y_t is the dependent variable, X_t the covariate matrix, ε_t is the associated error, and $\boldsymbol{\beta}$ is the vector of the regression parameters. The model errors have mean of zero, are not correlated, and have a constant variance. An additional requirement for the error terms is that they are normally distributed.

The 2 dependent variables that were modeled were the 2 extraction rates described above. The explanatory variables in these rates were the presence of a Dental Specialty Center, the HDI, and the Oral Health Teams and the time (the order of the observations).

As the data are time-series, the time covariate was included in the regression models to incorporate the correlation structure of the data. For example, a linear regression model with the intercept and the time variable is a nonstationary ARIMA model. An autoregressive component with an order of 1 was included in the models of the tooth-extraction rates by population based on the Oral Health Team coverage to meet the independent assumptions of the model residuals.[18] A logarithmic transformation of all of the tooth-extraction rates was applied to stabilize the variance and make the data closer to a probability normal distribution.

Therefore, as the rates were calculated separately by each covariate, 8 models were analyzed as follows:

(1) Model 1: The tooth-extraction rate via primary care in Brazil (15-y time-series)
(2) Model 2: The tooth-extraction rate for the Brazilian population (15-y time-series)
(3) Figure 3

(a) The tooth-extraction rate via primary care calculated for the municipalities according to the HDI (15-y time-series)
(b) The tooth-extraction rate via primary care calculated for the municipalities according to the Dental Specialty Center (9-y time-series)
(c) The tooth-extraction rate via primary care calculated for the municipalities according to the Oral Health Teams (13-y time-series)

(4) Figure 4
(a) The tooth-extraction rate by population calculated for the municipalities according to the HDI (15-y time-series)
(b) The tooth-extraction rate by population calculated for the municipalities according to the presence of a Dental Specialty Center (9-y time-series).
(c) The tooth-extraction rate by population calculated for the municipalities according to the Oral Health Teams (13-y time-series).

The covariate time was common in all of the models and the trend was the same for the 2 groups in the same model. The assumptions of the regression techniques were checked via an analysis of the model residuals, and hypothesis tests were performed for the regression coefficients. For each of the 8 final models, the set values or estimates of the average number were calculated, in addition to the 95% CIs for the average rate. Finally, 8 charts were constructed. To verify if the coefficients of the covariates in the regression model were significant, Student *t* test was used, with $P < 0.05$ considered as statistically significant. The analysis of the rates was performed using a logarithmic scale, as described previously. However, to aid in the understanding of the graphics, the dependent variables were presented using the original scale for the data. R[19] (R Foundation, Vienna, Austria) was used for the statistical analyses.

RESULTS

The total number of primary dental care procedures performed by the SUS during the 15 years was 1,590,103,988 procedures. Of these, there were 161,812,852 tooth extractions, which ranged from 10,490,997 extractions in 1998, to 10,674,084 extractions in 2012. In 1998, 87,205,727 primary dental care procedures were performed, and this number increased to 129,964,282 in 2012. A total of 360,175,189 first dental visits were performed from 1998 to 2012. In 1998, 50% of the municipalities performed up to 971 first dental visits. In 2012, the median increased to 1264. The Oral Health Team coverage in each municipality ranged from 0.00% to 3.74% in 2001 (median 0.00) and from 0.00% to 7.25% in 2012 (median 0.83%).

There has been an overall reduction in the tooth-extraction rate via primary care procedures ($P < 0.001$) (model 1) (Figure 1), but there has been no significant change in the overall tooth-extraction rate in the Brazilian population ($P = 0.11$) (model 2) (Figure 2).

Figure 3 presents the models of the tooth-extraction rates via primary care procedures calculated separately according to the HDI, the presence of a Dental Specialty Center, and the Oral Health Teams. The analysis of the model 3(a) data showed that the effect of time was negative and was statistically significant ($P < 0.001$). Each year, there was a decrease of 0.044 in the average log of the tooth-extraction rate in the municipalities with HDIs above and below the median, and the effect of the

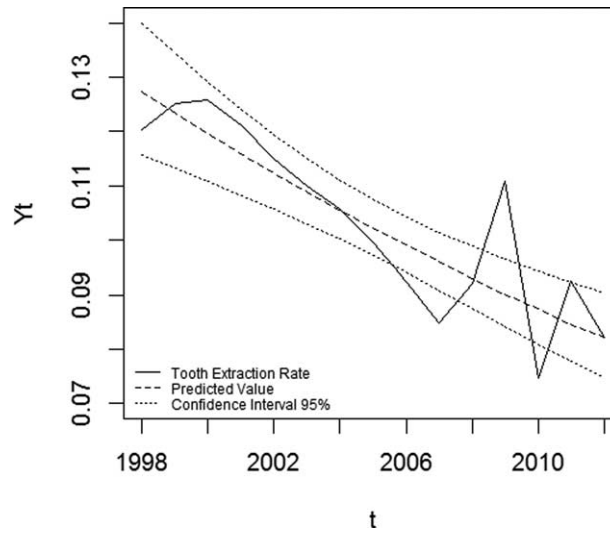

FIGURE 1. The time-series of the tooth-extraction rates via primary care procedures in Brazil from 1998 to 2012.

HDI was significant ($P < 0.001$). The municipalities with a lower HDI (below or equal to the median) had a log of the extractions rates that were 0.738 higher, on average, than those municipalities with higher HDIs (above the median).

In model 3(b), the analysis showed that the effect of time was negative and was not statistically significant ($P = 0.23$). Each year, there was an average decrease of 0.014 from the log of the tooth-extraction rate in the municipalities both with and without a Dental Specialty Center, and the effect of a Dental Specialty Center was significant ($P < 0.001$). The municipalities without a Dental Specialty Center had a log of the tooth-extractions rates that were 0.452 higher, on average, than those municipalities with Dental Specialty Centers. Therefore, the average tooth-extraction rates in the municipalities with and without Dental Specialty Centers were different at the 5% significance level for all of the analyzed time periods because the CIs did not intersect.

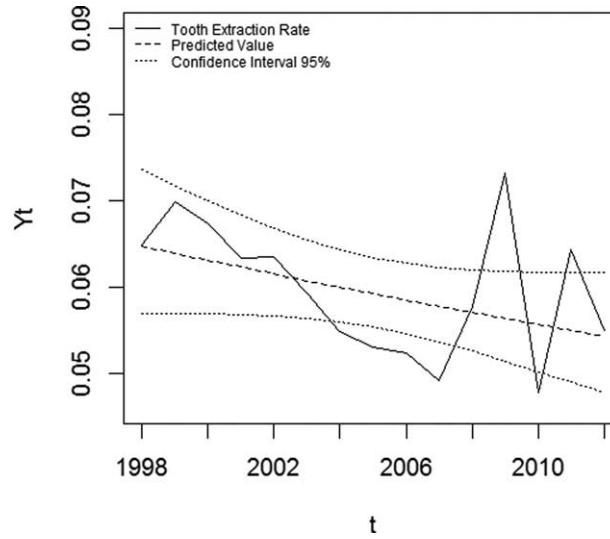

FIGURE 2. The time-series of the tooth-extraction rates based on the population in Brazil from 1998 to 2012.

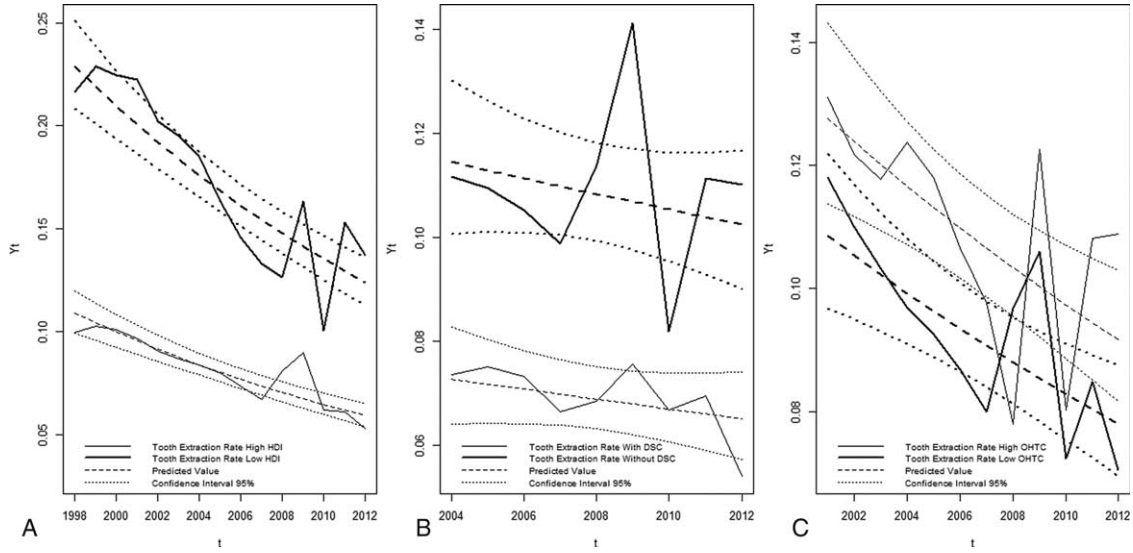

FIGURE 3. The time-series of the tooth-extraction rates via primary care procedures according to the Human Development Index (HDI) (A), the presence of a Dental Specialty Center (DSC) (B), and the Oral Health Teams Coverage (OHTC) (C) in Brazil from 1998 to 2012.

Model 3(c) showed the same statistical effect of time ($P < 0.001$). Each year, there was a decrease of 0.030 in the average log of the tooth-extraction rate in the municipalities with Oral Health Team coverage that were greater or less than the median, and the effect of the Oral Health Teams was significant ($P = 0.01$). The municipalities with lower coverage (below or equal to the median) had a log of tooth-extractions rates that were 0.162 lower, on average, than those municipalities with greater coverage. The means of the tooth-extraction rates in the municipalities with the lowest and highest Oral Health Team coverage were different at the 5% significance level, from 2002 to 2008.

Figure 4 presents the different models of the tooth-extraction rates by population and calculated separately according to the HDI, the presence of a Dental Specialty Center, and the Oral Health Teams. The analysis of the model 4(a) data showed that the effect of time was negative, but was not statistically significant ($P = 0.30$), and each year, there was a decrease of 0.009 in the average log of the tooth-extraction rate in the municipalities with an HDI below or above the median. The effect of the HDI was important and significant ($P < 0.001$). The municipalities with a lower HDI (below or equal to the median) had a log of the extractions rates that were 0.733 higher, on average, than those municipalities with higher HDIs

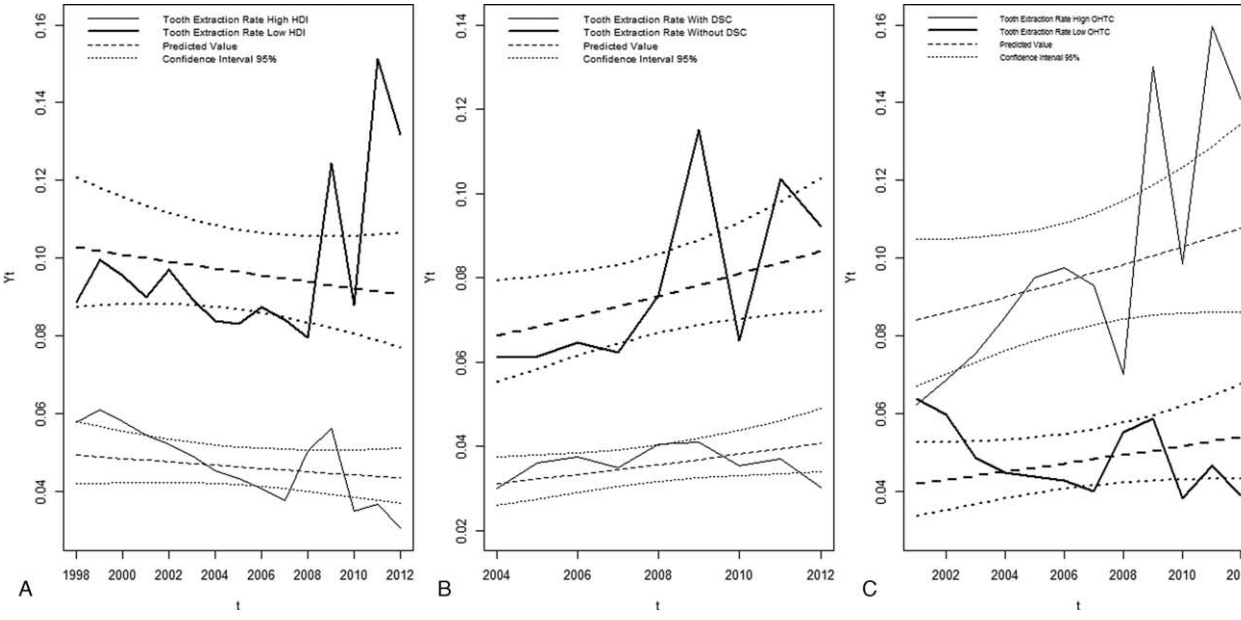

FIGURE 4. The time-series of the tooth-extraction rates based on the population according to the Human Development Index (HDI) (A), the presence of a Dental Specialty Center (DSC) (B), and the Oral Health Teams Coverage (OHTC) (C) in Brazil from 1998 to 2012.

(above the median). The means of the tooth-extraction rates in the municipalities with HDIs that were lower or higher than the median were different at the 5% significance level for all of the analyzed time periods.

In model 4(b), the analysis showed that the effect of time was statistically positive and significant ($P = 0.04$). Each year, there was an increase of 0.033 in the average log of the tooth-extraction rate in the municipalities with or without a Dental Specialty Center, and the effect of a Dental Specialty Center was significant ($P < 0.001$). The municipalities without a Dental Specialty Center had a log of the tooth-extractions rates that were 0.752 higher, on average, than those municipalities with Dental Specialty Centers. The mean extraction rates in the municipalities with and without a Dental Specialty Center were different at the 5% significance level for all of the analyzed time periods.

The model 4(c) analysis showed that the effect of time was positive, but it was not statistically significant ($P = 0.59$), but the effect of the Oral Health Team coverage was significant ($P < 0.001$). The municipalities with lower coverage (below or equal to the median) had a log of tooth-extractions rates that were 0.554 lower, on average, than those municipalities with greater coverage. The average extraction rates in the municipalities with the lowest and highest coverage were the same until 2001, and then they were different at the 5% significance level, from 2002 to 2008.

DISCUSSION

In this 15-year time-series study on tooth extraction in Brazil, the trend towards a reduction in tooth extraction during the overall time period was observed, especially when considering the tooth-extraction rate via primary care procedures. The rates are, on average, lower in municipalities with better HDI values and access to secondary care. On the contrary, the rates are, on average, higher in the municipalities with higher Oral Health Team coverage.

Over the 15-year period that was analyzed, Brazil went through several social and health changes that may explain the reduction in tooth extractions. Public policies for oral health[10] and social inclusion[20] have been implemented, which have made access to dental care easier, in addition to improved income and living conditions in the population. However, the reduction in the tooth-extraction rate in the overall population was less evident than the reduction observed when analyzing the tooth-extraction rate during other primary care procedures. This shows that the tooth-extraction rates in the general population have been relatively constant. The maintenance of the tooth-extraction rates in the population as a whole is likely due to the low levels of dental care coverage in the public sector, which changed from 12.6% in 1998 to 13.8% in 2012.[21] Despite the creation of the SUS, which is a universal and free system from a legal point of view, there is still limited coverage in the Brazilian population.[22] Nevertheless, among the SUS users, there has been a change in the care profile. This aspect is interesting because it is aligned to the National Oral Health Policy that aims to meet the needs of primary care, improve the oral health status of the population, and overcome the current sociodemographic inequalities.[10]

Whereas the HDI measures the progress of a nation from 3 dimensions (income, health, and education[11]), the impact of this index on the tooth-extraction rates can be explained by the influence of the existing social and economic factors on oral health,[7,23,24] and specifically on tooth extraction.[3,6,25,26] The locations with poorer social and economic conditions generally have a greater need for restorative and surgical interventions.[4–8,27] Moreover, the lack of access to treatments that help to prevent the need for tooth extractions in these populations may also be present. The progress in reducing social inequality is extremely relevant to the improvement of the health conditions in these human populations.[28,29]

The lowest tooth-extraction rates that were observed in municipalities with access to secondary care via a Dental Specialty Center can be explained by the ability to perform clinical procedures that prevent tooth extraction. The implantation of Dental Specialty Centers has been the current national oral health strategy to ensure access to secondary care in Brazil. It is important to understand that primary care is linked to secondary care because both are essential for comprehensive oral health care.[10,30] The Dental Specialty Centers promote the secondary and tertiary prevention of health issues through early diagnosis and prompt treatment, in addition to limiting the damage and rehabilitation of cases,[31] which contributes to the reduction of tooth extraction. The procedures performed by Dental Specialty Centers include surgery, periodontics, endodontics, and prosthesis. As these procedures are not offered in primary care, it is assumed that in municipalities that do not have Dental Specialty Centers, the problems that are related to this level of care are being addressed via tooth extractions.[32]

The highest rates in municipalities with higher Oral Health Teams can be explained by the recent implementation of Oral Health Teams with the accumulation of needs over the years,[33] the availability of visits without planning and programming of activities,[34] the profile and attitudes of the dental professionals,[3,32] and the type of dental emergencies that are deemed as a priority targets for direct resources are not sufficient to meet all of the needs of the population.[16]

Ecological studies show limitations that are inherent to the fact that they are observational studies of aggregate data. A limitation of this study is the use of secondary data from health information systems. The data for each variable were collected by different public health providers, and the reproducibility cannot be accessed. The big jumps/falls in observed rates between 2008 and 2010 could be due to changes in the registration of tooth extraction in the National Health Information System. In addition, we did not evaluate the private dental practices in Brazil. Other variables that could be associated with the oral health conditions, such as sanitation and access to food, were also not evaluated because the information was not available in the databases that were used. Apart from this, the trends identified in our study should not be extrapolated to individual level. It could be interesting to identify the reasons of tooth loss to remove from database tooth loss with no impact in quality of life. However, it was not possible to identify tooth extractions caused by other reasons, such as dental trauma or orthodontic procedures. Tooth extraction caused by trauma should impact quality of life,[35] but tooth extraction with orthodontic indication, probably do not affect. However, in Brazil and other health services, the prevalence of tooth extraction with orthodontic indication is low, varying from 5.7%[36] to 6.9%.[37] In South Wales, this prevalence was quite similar to the prevalence in Brazil (5.5%).[38] Moreover, in poor population, as users of oral health services in SUS,[39] the frequency of tooth loss by dental caries and periodontal disease may be higher than in other health services, considering the burden of oral diseases in this group.[2,40] Thus, the lack of information about other reasons for tooth loss probably may not affect our results.

This study presents results that are particularly important for planning health care. Improvement in socioeconomic conditions, and access to fluoride and to secondary care may decrease tooth loss.[2,10,40] Investments in individual and collective actions aimed at the promotion, prevention, and treatment of health problems, applying the common risk factor approach into a broader social-determinant–related perspective.[40] These strategies would enable healthcare professionals to pay attention to the individual's health and to the public health, thus reducing the level of tooth extraction.

CONCLUSIONS

In general, Brazil has shown a decrease in the trend to extract permanent teeth over the 15 years that were analyzed in this study. Human development and access to oral health services have both influenced the tooth-extraction rates.

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