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Factors affecting dental fluorosis in low socioeconomic status children in Mexico

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Objective: To assess the association between dental fluorosis and maternal education in schoolchildren of medium and low socioeconomic status in a low income region of Mexico. ***Design:*** Cross-sectional study. ***Settings***: Public schools in the south-central region of Oaxaca, Mexico where the mean fluoride water concentration was 1.01 mg/L (SD 0.21; range 0.71-1.40). Fluoridated salt (200mgF/kg) was available in the region. ***Participants***: 794 schoolchildren. ***Methods***: To identify the socioeconomic status of the participants, the Bronfman index was used. Dental fluorosis was assessed applying the Thysltrup-Fejerskov Index, (TF). ***Results*:** The children's mean age was 10.4 (SD 1.2) years. The prevalence of dental fluorosis (TF>0) was high 95.7% and 45.2% of the children showed dental fluorosis of TF≥4. The percentage of children showing TF≥4 was 48.8% where their mothers' education was <6 years of schooling compared to 36.7% among other children ($p<0.001$). The multinomial logistic regression model using as base outcome category TF≤2 showed that severe forms of fluorosis (TF≥4) were associated with the consumption of boiled water, (OR= 1.65, p=0.039) of fluoridated salt (OR= 2.61 p=0.001), high brushing frequency (OR=3.12, p=0.001) and lower maternal education (OR=1.71, p=0.007). ***Conclusions***: A high prevalence of dental fluorosis was observed in the study region. An unequal burden of fluorosis in aesthetically objectionable categories was found in children exposed to several sources of fluoride and whose mother had lower educational level.

Key words: *dental fluorosis, socioeconomic factors, maternal education, schoolchildren, public dental health, México*

Introduction

Poverty and inequality affects access to education, dignified work, housing, and health services. There is evidence that suggests a socioeconomic gradient in oral health (Marmot *et al*., 2011). Oral diseases have a multifactorial etiology. Fisher-Owens *et al*. (2007) described a conceptual model of the influences of children´s oral health that emphasized the importance of socioeconomic, behavioral, and environmental factors as determinants of oral health. It has been found that maternal education has an impact on the children's oral health status (Carta *et al.,* 2014; Carvalho *et al.,* 2014). However, there is little information of its role in the development of dental fluorosis.

Epidemiological information showed that dental fluorosis prevalence has increased in many countries. This condition affects the appearance and the structure of dental enamel due to the ingestion of excessive quantities of fluorides during critical periods of amelogenesis (Aoba and Fejerskov, 2002). In Mexico, there are various regions where fluorosis is endemic primarily due to the concentration of fluoride in water and the high altitude of the communities (Pontigo-Loyola *et al.,* 2008). Some 18.4% of Mexican children live in communities with fluoride concentrations higher than 1.1 mg/L. The results of studies on the association between socioeconomic status (SES) and dental fluorosis had found equivocal results. Some studies detected that children in a lower SES showed a higher prevalence of fluorosis (Pontigo-Loyola *et al*., 2014; Villa and Guerrero, 1996), but other studies indicate the opposite (Maupomé *et al.,* 2003). The education of the mother or of both parents is a socioeconomic factor likely to be associated with dental fluorosis because of its relationship with the use of fluoridated products (Feldens *et al*., 2010; Meneghim *et al*., 2007). For example, in Brazil children with less educated parents used tooth paste with higher fluoride concentration than the children of parents with higher education (Martins *et al*., 2011).

There is insufficient information on the impact of socioeconomic status and particularly maternal education, on oral health of children who live in regions with an elevated concentration of fluoride in the water and who are exposed to multiple fluoride sources. The objective of this study was to assess the association between dental fluorosis and maternal education in children of medium and low socioeconomic status, living in communities with water fluoride concentrations above 0.70 mg/L, in a low income region of Mexico.

Method

This cross sectional study was conducted in the state of Oaxaca, one of the four states with the highest level of poverty in the Mexico. In 2010, 67.6% of the population of this state was below the poverty line (CONEVAL, 2012). To identify the study group, we constructed a sampling frame containing a list of the communities in the south central region of Oaxaca (Central Valleys and South Sierra).

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Well water fluoride concentration data from the National Water Commission (CONAGUA), were added for the wells serving the region to aid sample selection. Later, the water fluoride concentrations from the 15 community wells supplying the sampled areas were confirmed by taking water samples for analysis according to the official Mexican standard (NOM-201-SSA1-2002) using a potentiometer and a fluoride specific electrode (Hanna, HI2550-01). The results showed an average fluoride concentration of 1.01 mg/L (SD 0.21; 95%CI 0.99,1.03; range 0.71–1.40 mg/L).

To investigate dental fluorosis, seven of the region's 30 communities with water fluoride concentrations ≥0.71 mg/L were randomly chosen. Their elevation above sea-level was between 1,520 and 1,560 metres. The mean water fluoride concentration in these communities was 1.01 mg/L (SD 0.21) ranging from 0.71 to 1.40.

All 17 public primary schools in the selected communities agreed to participate in the study. The children included in the study were 9 to 13 years of age, currently attending those schools, born in the community and with parents who signed the consent form to allow their participation. This age group was selected considering the number of permanent teeth present in the oral cavity at these ages. Exclusion criteria were those who had lived more than six months outside of the community or who did not wish to participate.

The sample size calculation for the logistic regression estimated an odds ratio (OR) of 1.5 between dental fluorosis (TF≥4) and SES (α=0.05, power=0.85). The total number of participants required was 785, assuming a prevalence of fluorosis in the very low SES group of 50% (Hsieh *et al.,* 1998). The protocol for the study was approved by the ethics committee of the Graduate School of Dentistry in the National Autonomous University of Mexico then data were collected between September and December 2014.

To evaluate dental fluorosis, the Thylstrup and Fejerskov (1978) index was used for all permanent teeth present then children were assigned a fluorosis level based on the tooth with the greatest level of fluorosis. The three examining dentists took a calibration course supervised by an experienced oral epidemiologist to standardize the TFI assessment and obtained Kappas >0.80 for inter- and >0.89 for intra-examiner consistency.

The children were given a questionnaire collecting data on socioeconomic status, dental hygiene practices, their main drinking water source (tap, bottled or other) and the most frequent type of salt consumed (fluoridated or not). The survey was completed at home and with parental help. To verify the clarity of the questionnaire, a group of 32 children with an educational level equivalent to their grade in school were asked if it was necessary to modify the questions and their suggestions were incorporated. Focus groups of mothers also tested the questionnaire and their suggestions were accepted. The questionnaire obtained a Cronbach's alpha of 0.86 and an intraclass correlation coefficient of 0.79.

To identify the socioeconomic status of the participants, the Bronfman index was used (Bronfman *et al.,*1988). To construct this index, a living conditions index (LCI) is first created. This index considers the type of flooring in the house (tile, cement, or earth), the location of available water (inside, outside, or travelling required to collect water), the system for removing waste water (drainage system or other forms of eliminating excrement), overcrowded housing (number of persons/room classified in three groups: ≤1.5, 1.6–3.5, ≥3.6). LCI scores ranging from 0 to 8 were mapped to three LCL categories: LCI score 0-3 to very poor, scored 0; LCI 4 to poor,1; and LCI 5-8 to medium, 2. Additionally, the level of education obtained by the head of the household (LE) was categorised as: low, ≤3 years of schooling, coded 0; intermediate, 3 to ≤6 years, 1; and high for ≥7 years, 2. To calculate the Bronfman index, LCL and LE scores were added, creating three SEP categories: very poor for scores 0-1; poor for score 2; and medium for scores 3-4. In the present study 18% of the children belonged to female-headed single parent families and 4% of the children came from a family with a female head of the household due to the father migrating to the United States. Maternal educational level was assessed based on their number of school attendance years.

To measure the association between the maternal education and the variables of interest, the Pearson χ^2 was used for categorical variables and the Kruskal Wallis test for differences in means. Multinomial logistic regression models were generated using the presence of fluorosis in three categories: TF≥4, TF=3 and TF≤2, this last group was used as the reference category for the regression model. Age, gender, drinking boiled water, using bottled water, toothpaste use during in the first five years of life and type of salt consumed, SES and mother´s educational level were the independent variables. The models were constructed with standard robust errors because the children were grouped into clusters according to their community of residence. Interactions in the logistical regression models were tested. Odds Ratios (OR) and 95% confidence limits were obtained. The level of statistical significance was α=0.05. The STATA v.12 statistical package was used for data analysis (StataCorp. 2011. TX).

Results

Of the 975 children invited to participate, 820 (84.1%) had parental consent. Of these, 26 were excluded based on the criteria described above, leaving 794 (81.4%) with data for analysis. Their mean age was 10.4 (SD 1.2) years and 52.4% were girls. Table 1 presents the children's drinking water practices, toothpaste use and other characteristics The main source of drinking water for 70.9% was bottled water and 14.7% taking water directly from the tap leaving 14.4% from other sources such as a well at their home, local springs and water tank trucks. About half the children drank boiled water sometimes or daily (47.7%), usually boiled tap water (81.0%). Fluoridated salt was consumed by 93.9% of the children. About two thirds of the sample brushed their teeth one or more times a day and a similar fraction used an adequate amount of toothpaste (≤ pea size). Only 3.9% of the children did not use fluoridated toothpaste with most (81.0%) used a brand containing sodium fluoride at 1,450 ppm F^-, and 15.1% with sodium fluoride or stannous fluoride in a lower concentration (1,100 ppm F^-).

In general, the mothers' the educational level was low: 70.1% having less than six-years of schooling. The children of these less educated mothers were more likely than the others to: drink tap water (18.0% vs. 7.2%, p<0.001). They were also less likely to: consume bottled water (63.6% vs. 88.2%, p<0.001) and brush teeth more frequently (8.3% vs. 4.2%, p<0.001) (Table 1). No significant differences were observed in the concentration of fluoride in tap water by maternal education with mean tap water fluoride concentrations being 1.00 and 1.02 (SD 0.21, p=0.292). Additionally, an association was observed between maternal educational level and SES, in the medium SES group 70.9% of mothers had six or more years of education, but only (11.4%) in the very low SES group (p<0.001).

The distribution of the children by SES was 36.9% in the medium, and 26.2% and 36.9 % in the low and very low SES, respectively. More children in the very low SES group than those in the medium group: drank tap water (20.5% vs. 6.8%, p<0.001) and sometimes or always drank boiled water (48.8% vs. 34.4%) as shown in Table 2.

The sample children's prevalence of fluorosis (TF>0) was 95.7%. The distribution by each TFI score from 0 to ≥6 was: 34 (4.3%), 61 (7.7%), 142 (17.9%), 198 (24.9%), 252 (31.7%), 87 (11.0%), 20 (2.5%). An association between mother's education and fluorosis score was observed. For mothers with less schooling about half their children were in the severe categories (TF≥4) while this was about a third for the others (48.8% vs. 36.7, p<0.001 Similarly, children with severe fluorosis (TF≥4) were distributed across medium, low and very low SES groups as follows: 38.6%, 48.6% and 49.1% (p=0.018).

Table 3 shows the crude and adjusted OR obtained from the multinomial logistic regression models for dental fluorosis in three categories TF≥4, TF=3 with TF≤2 used as reference category. Included in the models were mothers' education, age, gender, type of water, salt, use of dentifrice (frequency of brushing and amount of toothpaste) and SES. The results for fluorosis TF=3 indicated that children of less educated mothers were more likely to show this level of fluorosis (OR=1.85, p=0.007), as did those who brushed their teeth three or more times a day (OR=2.50, p=0.001) or used larger than pea size amounts of toothpaste (OR=1.27, p=0.037). For the higher categories of fluorosis (TF≥4) a greater probability of fluorosis (TF≥4) was observed in: children of less educated mothers (OR=1.71, p=0.007), those consuming boiled water daily (OR=1.65, p=0.028, ref. not consuming boiled water); those consuming fluoridated salt (OR=2.61 p=0.001); and children with a higher frequency of tooth brushing (OR=3.12, p=0.001).

Table 1. Distribution of drinking water and tooth brushing practices, fluoridated salt consumption by mother´s years of schooling in communities in the south-central region of Oaxaca, Mexico: counts (percentages)

Characteristic	*Practice*	*Mother's years of formal schooling*		*Overall*	*P*
		Less than 6 years *n=557*	*6 years or more* *n=237*	*N=794*	
Drinking water	Bottled	354 (63.6)	209 (88.2)	563 (70.9)	<0.001
	Tap	100 (18.0)	17 (7.2)	117 (14.7)	
	Other [1]	103 (18.4)	11 (4.6)	114 (14.4)	
Drinking boiled water	No	284 (51.0)	131 (55.3)	415 (52.3)	0.439
	Sometimes	152 (27.3)	63 (26.6)	215 (27.1)	
	Daily	121 (21.7)	43 (18.1)	164 (20.6)	
Fluoridated salt consumption	No	32 (5.8)	16 (6.7)	48 (6.1)	0.586
	Yes	525 (94.2)	221 (93.3)	746 (93.9)	
Frequency of dental brushing [2]	Less than once a day	164 (29.4)	102 (43.1)	266 (33.5)	< 0.001
	1 to 2 times a day	347 (62.3)	125 (52.7)	472 (59.5)	
	3 or more times a day	46 (8.3)	10 (4.2)	56 (7.0)	
Amount of toothpaste [2]	Less or equal pea size	380 (68.2)	150 (63.3)	530 (66.8)	0.177
	Larger than pea size	177 (31.8)	87 (36.7)	264 (33.2)	
Socioeconomic status	Medium	125 (22.4)	168 (70.9)	293 (36.9)	< 0.001
	Low	166 (29.8)	42 (17.7)	208 (26.2)	
	Very low	266 (47.8)	27 (11.4)	293 (36.9)	

[1] Other source of drinking water included house's well, local water springs and water tank trucks; [2] Tooth brushing frequency and amount of toothpaste used during kindergarten years.

Table 2. Socioeconomic status and demographic characteristics water source and use of tooth paste of children of the south-central region of Oaxaca, Mexico: counts (percentages)

Characteristic	*Practice*	*Medium* *n=293*	*Low* *n=208*	*Very low* *n=293*	*Overall* *N=794*	*P*
Drinking water	Bottled	259 (88.4)	149 (71.6)	155 (52.9)	563 (70.9)	<0.001
	Tap	20 (6.8)	37 (17.8)	60 (20.5)	117 (14.7)	
	Other [1]	14 (4.8)	22 (10.6)	78 (26.6)	114 (14.4)	
Drinking boiled water	No	163 (55.6)	102 (49.0)	150 (51.2)	415 (52.3)	0.041
	Sometimes	79 (27.0)	60 (28.9)	76 (25.9)	215 (27.1)	
	Yes	51 (17.4)	46 (22.1)	67 (22.9)	164 (20.6)	
Fluoridated salt n (%)	No	16 (5.5)	11 (5.3)	21 (7.2)	48 (6.1)	0.596
	Yes	277 (94.5)	197 (94.7)	272 (92.8)	746 (93.9)	
Tooth brushing frequency [2]	Less than once a day	112 (38.2)	60 (28.9)	94 (32.1)	266 (33.5)	0.111
	1 to 2 times a day	166 (56.7)	133 (63.9)	173 (59.0)	472 (59.4)	
	Three or more day	15 (5.1)	15 (7.2)	26 (8.9)	56 (7.1)	
Amount of toothpaste [2]	Less or equal to pea size	189 (64.5)	146 (70.2)	195 (66.5)	530 (66.8)	0.410
	Larger than pea size	104 (35.5)	62 (29.8)	98 (33.5)	264 (33.2)	

[1] Other source of water included house's well, local water springs and water tank trucks; [2] Tooth brushing frequency and amount of toothpaste used during kindergarten years.

Table 3. Odds Ratios (OR) of the multinomial logistic regression model for dental fluorosis and drinking water practices and socioeconomics characteristics in schoolchildren from communities of the central area of Oaxaca

	Fluorosis index TF=3 (reference outcome TF≤2)				Fluorosis index TF≥4 (reference outcome TF≤2)			
Characteristic/Practice	*Crude OR (95%CI)*	*P*	*Adjusted OR (95%CI)*	*P*	*Crude OR (95CI)*	*P*	*Adjusted OR (95CI)*	*P*
Age	0.97 (0.82,1.15)	0.758	0.88 (0.78,1.01)	0.060	1.31 (0.96,1.78)	0.758	1.23 (0.84,1.79)	0.283
Gender								
Men (ref. Women)	1.03 (0.76,1.40)	0.833	1.01 (0.81,2.18)	0.940	1.22 (0.99,1.50)	0.057	1.21 (0.98,1.49)	0.079
Drinking tap water [1]								
Yes (ref. No)	0.91 (0.43,1.91)	0.795	1.09 (0.54,2.18)	0.815	0.91 (0.21,3.93)	0.795	1.18 (0.26,5.44)	0.827
Drinking boiled water (ref No)								
Sometimes	1.23 (0.87,1.78)	0.222	1.20 (0.76,1.90)	0.424	1.36 (1.07,2.83)	0.025	1.30 (1.00,1.70)	0.050
Daily	1.24 (0.70,2.10)	0.483	1.16 (0.66,2.02)	0.602	1.74 (1.04,1.78)	0.023	1.65 (1.03,2.65)	0.039
Tap water F (mg/L)	0.58 (0.21,1.69)	0.322	0.28 (0.54,1.42)	0.125	1.08 (0.44,2.66)	0.862	0.53 (0.05,5.99)	0.606
Fluoridated salt consumption								
Yes (ref No)	1.05 (0.54,2.04)	0.890	0.93 (0.51,1.70)	0.817	2.67 (1.61,4.41)	0.001	2.61 (2.08,3.26)	0.001
Tooth brushing frequency [2] (ref. Less than once a day)								
1 to 2 times a day	1.42 (0.70,2.86)	0.333	1.21 (0.67,2.21)	0.520	1.65 (0.70,2.86)	0.128	1.41 (0.69,2.89)	0.348
3 or more times a day	2.90 (1.67,5.03)	0.001	2.50 (1.43,4.37)	0.001	3.96 (2.62,5.98)	0.001	3.12 (1.81,5.37)	0.001
Amount of tooth paste [2]								
>pea size (ref. ≤pea size)	1.13 (0.95,1.35)	0.176	1.27 (1.02,1.59)	0.037	1.10 (0.76,1.59)	0.622	1.28 (0.88,1.87)	0.188
Socioeconomic status								
Low (ref. <Medium)	1.64 (0.79,3.41)	0.179	1.39 (0.94,2.06)	0.099	1.89 (0.71,5.07)	0.204	1.48 (0.87,2.53)	0.149
Very low (ref. <Medium)	1.35 (0.50,3.61)	0.555	1.04 (0.81,2.32)	0.892	1.78 (0.66,4.75)	0.252	1.37 (0.81,2.33)	0.243
Mother´s educational level								

[1]Drinking tap water: ‘Yes’ included children directly drinking tap water, ‘No’ included children drinking bottled water and water from house well, local spring and tank truck;
[2]Tooth brushing frequency and amount of toothpaste used during kindergarten years.

Discussion

The prevalence of dental fluorosis was high with 45.2% of the sample showing a TF ≥4, corresponding to changes in the appearance of the whole tooth surface and with TF= 5 or higher involving the loss of dental enamel. These fluorosis severity levels have a negative impact on the appearance of teeth and this could affect their function. Therefore it is important to identify risk factors of this condition. In the present study, SES was not associated with dental fluorosis, but maternal education was. The results indicated that children whose mothers had less than six-years of schooling showed a higher prevalence of dental fluorosis (TF≥4) than other children.

The association between maternal education and fluorosis is consistent with the results of previous studies. A study of Mexican adolescents in a region with high water fluoride concentration revealed that participants who belong to families where the head of the household had low level occupation and low educational attainment showed a higher fluorosis prevalence than those belonging to families with better SES (Pontigo-Loyola *et al.,* 2014).

The association between maternal education and fluorosis may be related to a more adequate use of fluoridated toothpaste in more educated groups. A study of Brazilian families showed that better educated parents tend to buy toothpaste specially formulated for children, reducing the amount of accidentally ingested fluoride and therefore risk of dental fluorosis (Feldens *et al.,* 2010). Additionally, maternal education impacts the children's diet and this could have an influence in fluoride consumption and absorption.

In our study, drinking boiled water was associated with dental fluorosis, possibly because boiling increases the fluoride content by concentrating salts. A study aimed at analyzing changes in fluoride concentration due to boiling the water found that boiling for 15 minutes doubled the levels found in non-boiled water (Grimaldo *et al*., 1995). However, in the present study, information on how long the water was boiled was not recorded. A study of water purification practices in rural Central America communities showed that water was boiled for long time periods, as the water container was left in the stove (Rosa *et al.,* 2010). Some rural communities in Oaxaca have similar traditional practices. More likely, shorter boiling periods would have less impact on the increment of fluoride in the water. It may be of interest to study water purification practices in the communities, particularly in those with endemic fluorosis, and to educate the parents to avoid unnecessarily long boiling periods. Further, boiling of water was associated with lower SES. More studies are required to identify how this practice is associated with other SES variables and with other health promotion practices, including those related to oral health.

The participating children drank water from several sources, although about 70% drank bottled water, which frequently has low water fluoride concentration (0.27 mg/L), they also consumed tap water because it is used for cooking purposes. In the Mexican context drinking bottled water is not restricted to high income groups or sophisticated consumers, as may be the case in developed countries. In Mexico bottled water is consumed because it is considered safe and its *per capita* consumption of bottled water is the highest in the world. (Euromonitor International, 2016). It is more likely that the lack of association between concentration of fluoride in tap water and dental fluorosis observed in the present study is due to the different sources of water consumed by children and the relatively low number of children exposed to high fluoride concentrations in tap water, as less than 20% of the children were exposed to higher than 1.1 mg/L F in tap water.

Given that only 3.9% of the children indicated not using fluoridated toothpaste, it is likely that the prevalence and severity of fluorosis that was observed in the children of Oaxaca was the result of exposure to several sources of fluoride (including toothpaste). The dentifrice brand most frequently used in the study group contained sodium fluoride (1,450 ppm F^-). Accordingly, the results showed an association between higher frequency of toothbrushing and dental fluorosis. Toothpaste has been shown to be a significant source of fluoride intake in Mexican children (Martinez-Mier *et al*., 2003)

Additionally, when we considered the factors that influenced the children's oral health at the community level, we found that fluoridated salt consumption was associated with dental fluorosis. In the study's Oaxaca region, artisanal salt is available mainly from traditional rural markets and it is used in traditional cooking. This product does not have fluoride added and it is sold in plastic bags without labels. The artisanal salt it is not in compliance with the official Mexican standard (NOM040-SSA1, 1993), which stipulates the addition of 200 (±50 mg) mg F/kg of table salt. This standard dates from 1993; consequently, children who consume fluoridated packaged salt have had access to this product since birth (Secretaría de Salud, 1995). Other studies have found an association between the consumption of fluoridated salt and dental fluorosis (Pontigo-Loyola *et al*., 2014). The provision of iodized but non-fluoridated salt should be considered in the region because the official Mexican standard stipulates the distribution of fluoridated salt only in regions with a water fluoride concentration of <0.7 mg/L (Secretaría de Salud, 1995).

The results showed that Oaxacan children with less educated mothers, consuming boiled water, fluoridated salt and brushing their teeth three or times a day were more likely to show dental fluorosis (TF ≥4). Future preventive programmes to reduce fluorosis in the studied region emphasise educating mothers and teach adequate water boiling practices. They might also include making available low-cost bottled drinking water with a low fluoride concentration and/or the installation of equipment for purifying tap water since access to better quality water is important for this region. Moreover, it is essential to inform the mothers about the appropriate use of fluoridated toothpaste to reduce excessive fluoride ingestion in these young children because of the often communicated message of fluoridated toothpaste's caries protection effect (Petersson and Bratthall, 1996). A Brazilian study found that parents in a dental education program that included counselling in adequate use of toothpaste during the first years of life of their children was associated with a lower prevalence of dental fluorosis at age of 8 to 12 (de Moura *et al*., 2013).

One of the limitations of the study was its cross-sectional design that cannot establish cause/effect relationships. Nevertheless, care was taken to include only those children who had lived in the region since birth. It is likely that the water fluoride concentration maternal education and other SES factors imposed on the children were present since their first years of life.

Conclusion

The children studied showed a high prevalence of dental fluorosis as did more frequent tooth brushing. Fluorosis affecting the appearance of the whole tooth surface was more evident in children with less educated mothers. Consuming boiled water and fluoridated salt increased the likelihood of fluorosis. A better understanding of the relationship between socioeconomic factors and oral health can contribute to the identification of educational strategies for the dental office and public health programmes tailored for particular population.

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