Impact of caries and dental fluorosis on oral health related quality of life: A cross-sectional study in schoolchildren receiving water naturally fluoridated at above-optimal levels.

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Abstract

Purpose: To evaluate the impact of caries and fluorosis on oral health related quality of life (OHRQoL) among schoolchildren living in areas with high concentrations of fluoride in water.

Methods: 524 schoolchildren (8-12-years-old) residing in rural communities in central Mexico were examined for oral hygiene, caries (International Caries Detection and Assessment System, ICDAS II), and fluorosis (Thylstrup and Fejerskov Index, TFI). OHRQoL was evaluated with the Child Perceptions Questionnaire for two age groups (CPQ_{8-10} and CPQ_{11-14}). Generalized Structural Equation Models (GSEM) were constructed for data analysis.

Results: Overall prevalence of caries was 88.5% and fluorosis 46.9%. Group 8-10-year-old: 48% of the children had advanced carious lesions in primary or permanent teeth (ICDAS≥4), 22.6% had moderate/severe fluorosis and 59.9% of children had an impact on OHRQoL. Schoolchildren with ICDAS≥4 were more likely [OR=1.75, (95%CI 1.34–2.28)] to suffer a negative impact on OHRQoL. Group 11-12- year-old: 19.9% of children had advanced carious lesions and 23.2% showed moderate/severe fluorosis. 67.3% of children reported had an impact on OHRQoL. Children 11-12-year-old with fluorosis (TFI≥4) [OR=2.39 (95%CI 2.12–2.69)], caries (ICDAS≥4) [OR=2.18 (95%CI 2.13–2.24)], and low brushing frequency [OR=2.04 (95%CI 1.21–3.44)] were more likely to have deterioration on OHRQoL.

Conclusion: A negative impact on OHRQoL was observed in children with caries and fluorosis.

Clinical relevance: Deterioration on OHRQoL found in children as a sequel of caries and fluorosis should be considered when designing health policies leading to prevention and effective health promotion programs, and incorporated to clinical guidelines for timely dental treatment.

Key words: Quality of life, dental caries, fluorosis, schoolchildren

Introduction

In recent years there has been an increased interest in research evaluating oral health-related quality of life (OHRQoL) [1, 2]. The driving force for this momentum has been the realization that health status must be examined in every dimension; not only the clinical aspects but also psychological and socio-behavioral antecedents and consequences of oral diseases. This attention has often been centred on dental caries, as it is highly prevalent in many countries [3, 4]. It can cause problems such as pain, discomfort while chewing, difficulties in sleeping, and aesthetic problems, among others; therefore, it seems intuitive it can affect quality of life [5, 6]. Studies of the association between caries and quality of life have inconsistent results across settings, however. For example, an association between dental caries and deterioration in quality of life was identified among Asian schoolchildren [6]. Conversely in Nigerian children no association was observed [7]. It is possible that the failure to identify a relationship between dental caries and OHRQoL is due to limitations in the criteria to evaluate dental caries; several indices do not consider the degree of tooth involvement. In recent years, more detailed caries indices have been developed to connote the stage of progression of the carious lesion. One such index is ICDAS (International Caries Detection and Assessment System); it discriminates between incipient lesions, and lesions encompassing larger portions of the tooth [8].

Dental caries has decreased on average in many developed and middle income countries, manly as a result of the widespread use of fluorides; however, fluorosis prevalence has often increased [9, 10]. Dental fluorosis is an irreversible defect in dental enamel formation resulting from chronic above-optimal ingestion of fluoride during tooth formation [11]. The clinical appearance of dental fluorosis may range from white spots to dark brown areas; pitting and fractures appear in severe cases [12, 13].

Children exposed to several sources of fluoride have an increased prevalence and severity of dental fluorosis [14, 15]. In Mexico, epidemiological studies found the presence of dental fluorosis mostly in the Central and Northern regions of the country [16-19]. The relationship of mild fluorosis with the enhanced exposure to small yet continuous amounts of fluoride through the national program to fluoridate domestic salt for human consumption has been established [20].

To assess OHRQoL several instruments have been developed such as the Child Perceptions Questionnaire (CPQ) [21] and Child Oral Impacts on Daily Performances Index (Child-OIDP) [22]. It is worthwhile noting that there have been few studies examining in detail the relationship between fluorosis and quality of life [23, 24]. There are studies where the presence of fluorosis in the mild or very mild fluorosis categories were associated with a positive impact on quality of life due to the whiter color of the teeth, which apparently made them more attractive [25]. In contrast, in Tanzania and in Mexico it was found that severe fluorosis categories had a negative impact on OHRQoL [26, 27].

We hypothesize that both caries and dental fluorosis affect OHRQoL in children; larger cavities and more severe forms of fluorosis may have greater impact on OHRQoL, compared to incipient carious lesions or milder levels of fluorosis. We also propose that the complex relationships between different oral conditions and their impact on OHRQoL could be more accurately discerned applying structural equation modelling (SEM). This approach allows for analysis of variables that are correlated, thereby affording a better understanding of the relationships between different health conditions and risk factors [28]. This technique has been sparsely applied in OHRQoL research [29].

Given the limited literature about perspectives of various age groups on dental conditions and OHRQoL, the aim of the present study was to evaluate the impact of dental caries and fluorosis on the OHRQoL among schoolchildren 8-12-year-old. SEM was added to the research approach to tease out specific pathways of influence.

Materials and methods

The Ethics Committee of the Division of Postgraduate Studies and Research, School of Dentistry, National Autonomous University of Mexico approved the study protocol (UNAM/PMDCMOS/221).

Research Location

The study area was located in a rural region in the southeast of the State of Morelos, Central Mexico. This location is rather typical of the heterogeneous living conditions and socio-economic situation of an emerging economy country such as Mexico. In the selected communities 85.7% of households had access to community water systems, 92.0% lived in neighbourhoods that had sewer systems, 37.5% of

inhabitants had finished elementary education, 8% of the population aged 6 to 14 did not attend school, 10.4% of the population aged 15 years or older was illiterate; considering living conditions (availability of electricity, overcrowded conditions, having toilet and having a refrigerator) this communities are classified in the top third poverty level in the State of Morelos [30]. Water wells that provide piped water in the study communities were sampled during both dry and raining seasons. The concentration of fluoride in the water wells ranged from 0.7 ppm to 1.61 ppm. To determine the fluoride concentration in drinking water a fluoride specific electrode (Orion ™) was used, following the standard technique; all samples were analyzed in duplicate [31].

Study population.

The study group was selected from two rural communities with different water fluoride concentration aiming to include children showing different levels of fluoride exposure and more likely different levels of dental fluorosis. The four elementary schools available in the communities were included and children 8-year-old and older were selected. Following the inclusion criteria, the participating children were born in the selected communities; the exclusion criteria were children who have lived outside of the study region for more than six months during their first seven years of life, or who had fixed orthodontic appliances. Informed consent was obtained from the parents of all individual participants included in the study. Sample size calculation to detect a difference in the proportions of poor OHRQoL between children with and without cavitated carious lesions were performed for α=0.05, β=0.20, and a probability of poor OHRQoL in the group without cavitated carious lesions P=0.12. The sample size estimated was 517 children. We allow for a non-response rate between 10%-12% or having exclusion criteria, 600 children were targeted to ensure about 540 participants. The estimation of sample size was also performed for dental fluorosis, resulting in a smaller sample size required (n=341) [32, 33].

A total of 600 children' parents were thus asked to allow their children to participate in the study, of which 550 parents signed the consent letter. Of the 550 children potentially eligible, 26 were excluded, either because they had orthodontic appliances, missing data in the oral clinical evaluation, or failed to a complete survey. The response rate was 91.7%. A cross-sectional study including the data from 524 schoolchildren was performed.

Study Variables

Variables were sex, age (years), tooth brushing frequency with fluoride toothpaste (number of times a day), Oral Hygiene Index Simplified (dichotomized cut-off point OHI-S≥2), dental caries in children aged 8-10-year-old in primary and permanent, and in children aged 11-12-year-old in permanent dentition using ICDAS criteria, in three categories ICDAS 0, ICDAS 1-3 and ICDA ≥4 [8]. Dental fluorosis was assessed through the Thylstrup and Fejerskov Index (TFI) and children TFI≥4 were classified as having moderate/severe fluorosis [34].

We chose ICDAS over the Decay, Missing and Filled index (DMFT) to distinguish between stages of carious lesions. ICDAS may have higher sensitivity than DMFT to detect associations with possible risk factors [35]. The validity and reliability of ICDAS has been tested [8].

The OHRQoL was evaluated using the Spanish version of the Child Perceptions Questionnaire [33, 36]. This instrument has the advantage of being designed for the assessment of OHRQoL in children of a specific age group (8-10-year-old and 11-14-year-old). Validity and reliability have been reported for Mexican children [33, 36]. The CPQ_{8-10} consists of 25 questions (score range 0-100), and CPQ_{11-14} of 37 (score range 0-148) questions asking about experiences during the last four weeks. They are divided into four domains: oral symptoms, functional limitations, emotional well-being and social well-being, using Likert-type scales (0-4). High values of the CPQ indicate higher deterioration in quality of life. The questionnaire was self-administered by study participants in the classrooms, filled in approximately 20 minutes. A trained dental assistant helped in the administration of the questioners in the classrooms and no time limits were set.

Oral examination

Oral exams were performed by one dentist with dental mirrors (# 5), WHO probes, and artificial light. Teeth were brushed before the oral examination. Adequate standardization with a Kappa=0.87 for caries and Kappa=0.85 for fluorosis was obtained; 10% of examinations were duplicated and the percentage of agreement was 88% and 87% for caries and dental fluorosis, respectively. Applicable infection control standards were followed [37].

Oral Hygiene Index Simplified (OHI-S) was applied; OHI-S was dichotomized at cut-off point OHI-S≥2, indicating fair/poor oral hygiene and OHI-S<2 good oral hygiene. ICDAS criteria for the assessment of dental caries was used [8]. This system includes the identification of non-cavitated incipient lesions (ICDAS 1-2), cavitated incipient lesions (ICDAS 3), underlying dentin shadow (ICDAS 4), lesions involving the destruction of less than half of the tooth surface (ICDAS 5) and more than half (ICDAS 6). Therefore, higher ICDAS scores indicate an increase in the severity of untreated carious lesions. Dental fluorosis was evaluated in the vestibular, occlusal and lingual surfaces of all erupted permanent teeth according to the TFI [34]. This index classifies fluorosis based on the histological changes of the tooth due to dental fluorosis. TFI categories ranged from 0 to 9; higher ordinal scale values indicate an increase in the severity of dental fluorosis.

Statistical analysis.

The description of the data is presented using means and standard deviations (SD) for continuous variables and as percentages for categorical variables. Comparisons between categorical variables were performed applying χ^2 test. Cohen's d effect size (ES) and 95% confidence intervals (95% CI) were calculated for the global CPQ score and its domains by dental caries (ICDAS) and dental fluorosis (TFI). Generalized Structural Equations Modelling (GSEM) was applied to study the impact of dental fluorosis and dental caries on OHRQoL. Dental fluorosis was classified in three categories (TFI 0, TFI 1-3 and TFI≥4); dental caries was also classified in three categories (ICDAS 0, ICDAS 1-3 and ICDAS≥4). Additionally, tooth brushing (with fluoride toothpaste) frequency and sex were included in the models. In this analysis the CPQ scores were dichotomized in: CPQ_{8-10} 3rd quartile (CPQ ≥28) and for CPQ_{11-14} 3rd quartile (CPQ≥49). The path coefficients obtained by SEM were exponentiated; odds ratios (OR) and their respective 95% CI were reported. Robust standard errors were obtained considering that the children were clustered in their communities. Analysis for the identification of outliers was performed using Mahalanobis' distance. One observation was identified as outliner and it was exclude from data analysis. Data analysis was performed using Stata 14 (Stata Corp, College Station, TX, USA).

Results

Basic results

A total of 524 schoolchildren were included in the study; 252 between 8-10-year-old, mean age 9.59 (± 0.51) years, and 272 between 11-12-year-old, mean age 11.40 (± 0.55). The percentage of girls in the 8-10-year-old group was 46.0% and in the 11-12-year-old it was 48.2%. In children 8-10-year-old, 80.5% brushed their teeth twice a day or more frequently; 85.3% did so in the 11-12- year-old group. Approximately, half (53.2%) of the schoolchildren had fair/poor oral hygiene (OHI-S≥2) and 46.8% had good oral hygiene in the 8-10-year-old group. Similarly, about half (45.6%) of schoolchildren had fair/poor oral hygiene (OHI-S≥2) in the 11-12-year-old group. Table 1 presents the distribution of the ICDAS score; overall 11.5% showed no clinical signs of caries (ICDAS =0), large carious lesions (ICDAS≥ 4) were observed in 19.9% of children in permanent teeth in the 11-12-year-old children, and approximately half (48.0%) of the children in the 8-10-year-old group showed large carious lesions, considering both primary and permanent teeth. The number of tooth surface affected by dental caries by age group is shown in Table 2. In the 8-10-year-old children, 64.8% of the tooth surface in the primary dentition and 85.0% in the permanent dentition did not showed signs of dental caries. More primary than permanent surfaces showed large lesions, 5.0% and 1.1%, respectively. In the 11-12-year-old children 74.5% of the surfaces were classified as sound and large lesions were detected in 2.2% of the surfaces.

Table 1. Distribution of 8-12-year-old children by caries experience using the International Caries Detection and Assessment System (ICDAS II)

	[a] 8-10-year-old [c] n (%)	[b] 11-12-year-old n (%)	[a] 8-12-year-old n (%)
ICDAS II 0	29 (11.5)	31 (11.4)	60 (11.5)
ICDAS II 1-3	102 (40.5)	187 (68.7)	289 (55.2)
ICDAS II ≥4	121 (48.0)	54 (19.9)	175 (33.3)
Total	252 (100)	272 (100)	524 (100)

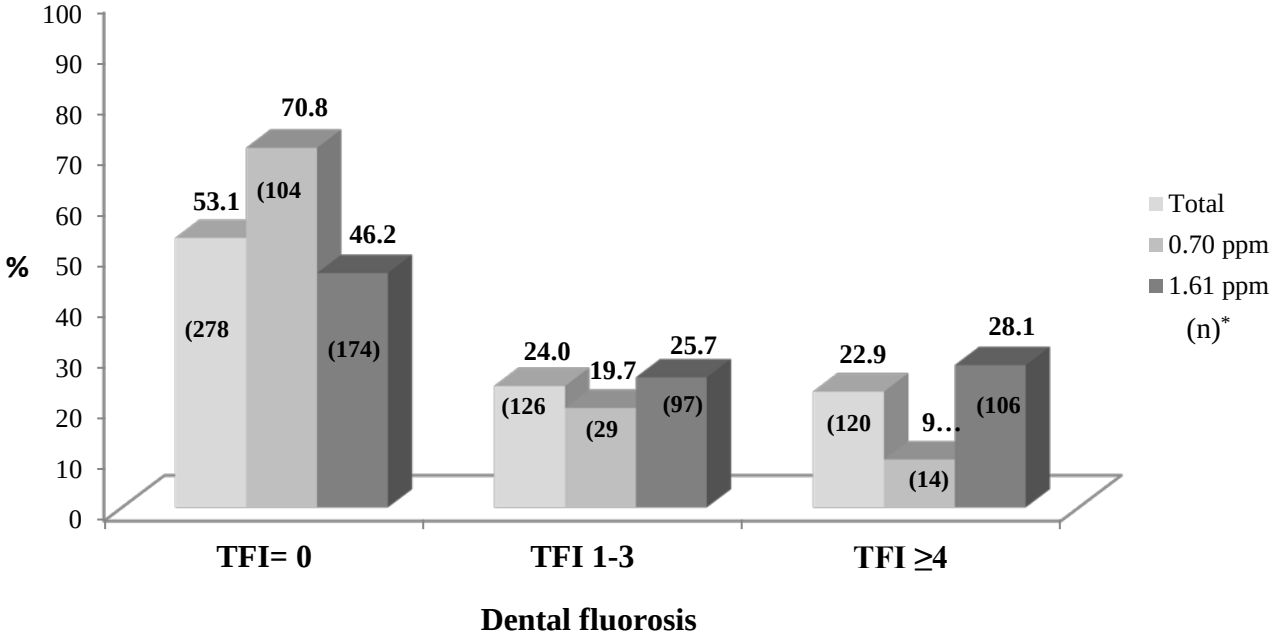
[a] Primary and permanent teeth, [b] Permanent teeth, [c] n=number of children.

Table 2. Distribution of tooth surfaces by International Caries Detection and Assessment System (ICDAS II) criteria in 8-12-year-old children

ICDAS II Score	Number primary tooth surfaces (%) 8-10-year-old	Number of permanent tooth surfaces (%) 8-10-year-old	Number of tooth permanent surfaces (%) 11-12-year-old	Total number of tooth surfaces (%) 8-12-year-old
ICDAS II 0	7815 (64.8)	17206 (85.0)	24671 (74.5)	49692 (76.0)
ICDAS II 1-2	1344 (11.2)	1675 (8.3)	3744 (11.3)	6763 (10.3)
ICDAS II 3	1239 (10.3)	702 (3.4)	2656 (8.0)	4597 (7.0)
ICDAS II 4	16 (0.1)	22 (0.1)	127 (0.4)	165 (0.3)
ICDAS II 5	1040 (8.6)	431 (2.1)	1200 (3.6)	2671 (4.1)
ICDAS II 6	600 (5.0)	215 (1.1)	721 (2.2)	1536 (2.3)
Total	12054 (100)	20251 (100)	33119 (100)	65424 (100)

The overall prevalence of dental fluorosis was 46.9%; severe fluorosis categories (TFI≥4) were observed in 22.9% of the children. Figure 1 presents the distribution of the fluorosis score by water fluoride concentration in the community of residence. The children living in the community with 0.7 ppm F showed a lower prevalence of fluorosis (29.2%) than children living in the 1.6 ppm F community (53.8%); higher categories of TFI (TFI≥4) were more frequently found in the children in the 1.6 ppm F community, compared with those in the 0.7 ppm F community: 28.1% and 9.5%, respectively ($p<0.0001$). The number of children showing TFI 0 was 142 (56.4%) and 136 (50.0%), TFI 1-3 53 (21.0%) and 73 (26.8%) and TFI≥4 57 (22.6%) and 63 (23.2%) of the 8-10 and 11-12-year-old children, respectively.

Figure 1. Prevalence of dental fluorosis in 8-12-year-old children across water fluoride concentration



TFI: Thylstrup & Fejerskov Index, *(n) number of children in each fluorosis category.

Child Perceptions Questionnaire in 8-10-year-old (CPQ $_{8\text{-}10}$)

In the general question about participants' perceptions of their oral health status, 22.2% rated their oral health as very good, 25.0% good, 31.8% medium and 21.0% as poor. Concerning general well-being, 49.6% of the children experienced a negative impact on their quality of life due to the conditions of their mouth; the distribution of the children's responses to this question was: 50.4% no impact, 28.1% low, 7.1% medium and 14.3% high impact. The results of the $CPQ_{8\text{-}10}$ indicated that 59.9% of schoolchildren had some impact on their quality of life as a result of the conditions of their mouth; by domain: 51.2% oral symptoms, 39.7% functional limitations, 43.7% emotional well-being, and 31.4% social well-being. The mean score of $CPQ_{8\text{-}10}$ in those children having an impact (CPQ>0) was 25.5 (± 31.1), and the median was 14 (IQR 6, 28).

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In the bivariate analysis, no statistical significant association was found between the score of each domains of the CPQ_{8-10} and caries in primary and permanent teeth (Table 3). Similarly, no significant association was detected between dental fluorosis status and the CPQ_{8-10} domains. Also, Table 3 shows the effect sizes of caries and fluorosis on the CPQ_{8-10} score. There were no statistically significant effect sizes in this age group.

Table 3. Mean CPQ_{8-10} score and effect size by dental caries (ICDAS II) and fluorosis (TFI) in 8-10-year-old schoolchildren

	[a] ICDAS 0 (n= 29)	ICDAS 1-3 (n= 102)	ICDAS 4-6 (n=121)	[b] p	[c] Effect size (95% CI)	[d] Effect size (95% CI)
[e] CPQ_{8-10}	20.5 (±19.5)	24.3 (±29.4)	27.7 (±33.0)	0.4432	0.14 (-0.27, 0.55)	0.24 (-0.17, 0.64)
Oral symptoms	4.1 (±4.3)	5.5 (±5.5)	6.1 (±6.0)	0.2321	0.25 (-0.16, 0.67)	0.34 (-0.70, 0.75)
Functional limitation	2.6 (±3.2)	5.2 (±5.9)	4.4 (±5.8)	0.0977	0.47 (-0.05, 0.89)	0.32 (-0.09, 0.77)
Emotional well-being	3.4 (±3.0)	5.2 (±5.9)	5.4 (±6.3)	0.2640	0.32 (-0.09, 0.74)	0.34 (-0.07,0.75)
Social well-being	7.5 (±8.4)	6.8 (±11.6)	8.7 (±12.9)	0.5166	-0.06 (-0.47, 0.35)	-0.10 (-0.31, 0.50)
	[f] TFI 0 (n= 142)	TFI 1-3 (n= 53)	TFI ≥4 (n= 57)	p	[g] Effect size (95% CI)	[h] Effect size (95% CI)
CPQ_{8-10}	25.2 (±30.7)	28.4 (±31.4)	23.5 (±28.4)	0.6863	0.10 (-0.21, 0.42)	-0.06 (-0.36, 0.25)
Oral symptoms	5.7 (±5.7)	6.0 (±5.8)	5.1 (±5.3)	0.6818	0.05 (-0.27, 0.36)	0.11 (-0.42,0.20)
Functional limitation	4.5 (±5.8)	5.1 (±5.0)	3.9 (±5.7)	0.5352	0.12 (-0.20,0.44)	-0.09 (-0.40,0.22)
Emotional well-being	4.8 (±5.8)	6.0 (±6.2)	4.8 (±5.7)	0.4231	0.20 (-0.11,0.52)	0.01 (-0.30,0.31)
Socialwell-being	7.6 (±12.0)	8.8 (±12.1)	7.4 (±11.6)	0.7894	0.01 (-0.22,0.41)	-0.02 (-0.33,0.29)

[a] ICDAS II (International Detection and Assessment System of primary+permanent teeth), [b] ANOVA p-value, [c] Cohen's d effect size between ICDAS 1-3 vs ICDAS 0, [d] Cohen's d effect size between ICDAS 4-6 vs ICDAS 0, [e] CPQ_{8-10} (Child Perception Questionnaire) higher values indicate poorer OHRQoL (Oral Health Related Quality of Life), [f] TFI (Thylstrup & Fejerskov Index), [g] Cohen's d effect size between TFI 1-3 vs TFI 0, [h] Cohen's d effect size between TFI ≥4 vs TFI 0.

The Generalized Structural Equation Model (GSEM) of the 8-10-year-old participants is presented in Figure 2, and path coefficients are provided. The presence of large (ICDAS≥4, p<0.005) or incipient (ICDAS 1-3, p<0.05) carious lesions and low tooth brushing frequency (<2/day, p<0.005) showed positive significant coefficients associated with poor CPQ_{8-10} scores. Additionally, a significant positive coefficient was found between low brushing frequency and the presences of large carious lesions (ICDAS≥4, p<0.005). Table 4 presents the odds ratios obtained in the GSEM analysis of CPQ_{8-10}. Children with dental caries were more likely to have poor CPQ_{8-10}; both incipient [OR=1.12, (95% CI 1.01-1.26, p=0.042)] and large [OR=1.75, (95% CI 1.34-2.28, p<0.001)] lesions were significant in the model. Additionally, lower brushing frequency was associated with poor CPQ_{8-10}, [OR=1.76, (95% CI 1.23-2.52, p=0.002)]. No association was found between low (TFI 1-3, p=0.777) and high (TFI ≥4, p=0.308) fluorosis levels with CPQ. Similarly, sex was not associated with CPQ_{8-10} (p=0.439). Tooth brushing frequency was associated with ICDAS≥4 [OR=2.04, (95% CI 1.26-3.30, p<0.005)] but not with ICDAS 1-3, neither fluorosis (Figure 2).

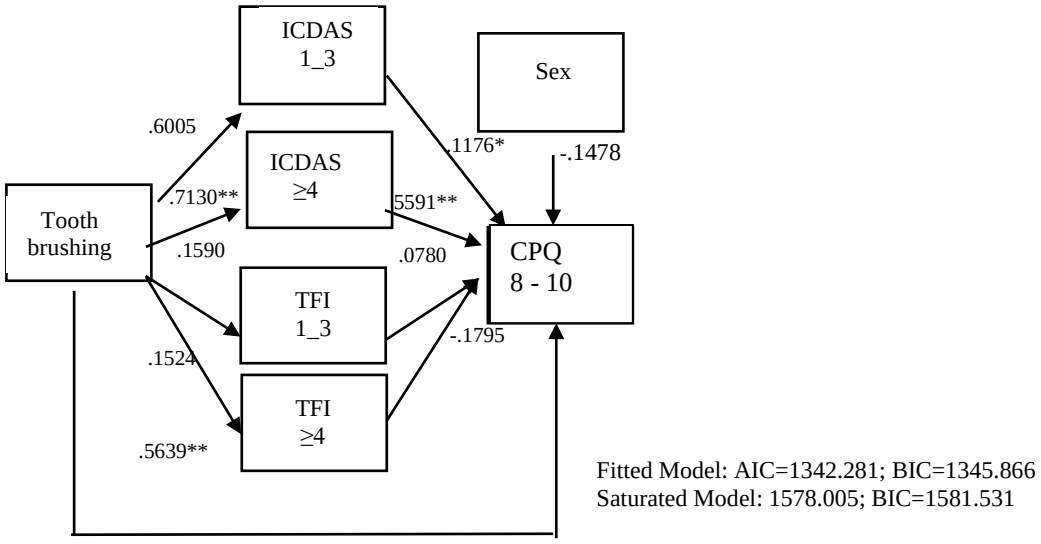

Figure 2. Graphical representation of the generalized structural equation model for children´s 8-10-years-old Quality of Life. Results from structural equation model (Logistic regression) coefficients. *p<.05, **p<.005. Reference Categories: Tooth brushing frequency <2/day, ICDAS=0, TFI=0, Sex=females. ICDAS= International Caries Detection and Assessment System, TFI= Thylstrup and Fejerskov Index.
AIC: Akaike´s information criterion; BIC: Bayesian information criterion.

Table 4. Odds ratios of the generalized structural equations model for oral health-related quality of life (CPQ_{8-10}) and dental caries, fluorosis index, tooth brushing frequency and sex in 8-10-year-old schoolchildren

Variables	OR (95% CI)	p
[a] Dental caries (ICDAS score)		
ICDAS 1-3	1.12 (1.01 – 1.26)	0.042
ICDAS≥4	1.75 (1.34 – 2.28)	<0.001
[b] Dental fluorosis (TFI)		
TFI 1-3	1.08 (0.63 – 1.85)	0.777
TFI≥ 4	0.83 (0.59 – 1.18)	0.308
[c] Sex (male)	0.86 (0.59 – 1.25)	0.439
[d] Tooth brushing frequency <2/day	1.76 (1.23 – 2.52)	0.002

[a] CI= confidence interval. Reference: [b] ICDAS=0 (primary+permanent teeth), [c] dental fluorosis TFI =0, [d] sex = female, [e] tooth brushing frequency≥2/day.

Child Perception Questionnaire in 11-12-year-old (CPQ_{11-14})

In the general question about perception of oral health status, 5.5% of schoolchildren considered their oral health as excellent; 5.9%, very good; 13.6% good; 64.7% medium; and 10.3%, bad. Regarding general welfare, 82.7% perceived that their quality of life was affected by the condition of his/her mouth; these responses were distributed as follows: 32.0%, slightly; 28.3%, somewhat; 9.2%, fairly; and 13.2%, a lot. About two thirds (67.3%) of schoolchildren reported their teeth or mouth condition having some impact on their quality of life in the past four weeks. The distribution by domain were 58.1%, oral symptoms; 52.0%, functional limitations; 54.8%, emotional well-being; and 40.1%, social well-being. The mean CPQ score was 46.1 (± 42.8), and the median 28 (IQR 16, 45).

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Table 5 shows the bivariate analysis of the CPQ_{11-14} score and its domains and caries, no significant associations were detected (p> 0.05). Conversely, the mean CPQ_{11-14} score was associated with dental fluorosis (TFI≥4, p=0.0147). Differences in the four domains were significant: oral symptoms (p=0.0391), functional limitations (p=0.0370), emotional well-being (p=0.0133), social well-being (p=0.0229). Also, Table 5 shows the effect sizes of caries and dental fluorosis on the CPQ_{11-14} score. On the global CPQ_{11-14}, the effect size of dental fluorosis in high categories (TFI≥4) (ES=0.35) compared with participants without this condition (TFI=0) was significant. Based on the Cohen's d statistic, 63.7% of the children showing TFI≥4 had a CPQ_{11-14} score above the mean observed in the group without dental fluorosis. Accordingly, ES were significant in the four domains of the CPQ $_{11-14}$. In the group showing TFI≥4 the percentage above the mean of the TFI=0 group, for each domain was: oral symptoms 61.8%, functional limitations 62.2%, emotional well-being 64.4% and social well-being 62.2%. Effect sizes of dental caries and CPQ $_{11-14}$ score were not statistically significant.

Table 5. Mean $CPQ1_{11-14}$ score and effect size by dental caries (ICDAS II) and fluorosis (TFI) in 11-12-year-old schoolchildren

	[a] ICDAS 0 (n= 31)	ICDAS 1-3 (n= 187)	ICDAS 4-6 (n=54)	[b] p	[c] Effect size (95% CI)	[d] Effect size (95% CI)
[e] CPQ_{11-14}	45.0 (±41.9)	45.9 (±41.1)	47.3 (±42.3)	0.9687	0.02 (-0.36, 0.40)	0.06 (-0.39, 0.50)
Oral symptoms	7.1 (±6.3)	7.6 (±6.7)	7.4 (±6.5)	0.9333	0.07 (-0.31, 0.45)	0.05 (-0.40, 0.49)
Functional limitation	10.3 (±10.4)	9.8 (±10.5)	10.3 (±10.5)	0.9281	-.0.05 (-0.43, 0.33)	0.01 (-.44, 0.45)
Emotional well-being	10.2 (±10.7)	10.4 (±10.9)	11.4 (±10.8)	0.8101	0.02 (-0.36, 0.40)	0.12 (-0.33, 0.56)
Social well-being	13.0 (±14.7)	13.6 (±13.7)	13.9 (±15.4)	0.9647	-0.04 (-0.34, 0.42)	-.06 (-0.39, 0.50)
	[f] TFI 0 (n= 136)	TFI 1-3 (n= 73)	TFI ≥4 (n= 63)	p	[g] Effect size (95% CI)	[h] Effect size (95% CI)
CPQ_{11-14}	43.9 (±39.1)	39.3 (±34.6)	58.8 (±50.0)	0.0147	-0.13 (-0.41, 0.16)	0.35 (0.05, 0.65)

Oral symptoms	7.2 (±6.5)	6.5 (±5.5)	9.3 (±7.7)	0.0391	-0.11 (-0.39, 0.18)	0.30 (0.10, 0.60)
Functional limitation	9.4 (±10.2)	8.5 (±8.7)	12.8 (±12.4)	0.0370	-0.09 (-0.38, 0.19)	0.31 (0.01, 0.61)
Emotional well-being	9.9 (±10.7)	9.0 (±9.0)	14.0 (±12.3)	0.0133	-.09 (-0.38, 0.20)	0.37 (0.07, 0.67)
Social well-being	13.1 (±12.7)	11.0 (±12.3)	17.6 (±17.9)	0.0229	-0.17 (-0.45, 0.12)	0.31 (0.01, 0.61)

[a] ICDAS II (International Detection and Assessment System II of permanent teeth), [b] ANOVA p-value, [c] Cohen's d effect size between ICDAS 1-3 vs ICDAS 0, [d] Cohen's d effect size between ICDAS 4-6 vs ICDAS 0, [e] CPQ_{11-14} (Child Perception Questionnaire) higher values indicate poorer OHRQoL (Oral Health Related Quality of Life), [f] TFI (Thylstrup & Fejerskov Index), [g] Cohen's d effect size between TFI 1-3 vs TFI 0, [h] Cohen's d effect size between TFI ≥4 vs TFI 0.

The graphical representation of the model of OHRQoL of the 11-12-year-old participants is presented in Figure 3, and path coefficients are provided. The presence of large (ICDAS ≥4, $p<0.001$) or incipient (ICDAS 1-3, $p<0.001$) carious lesions and low tooth brushing frequency ($p<0.01$) showed positive significant coefficients associated with poor CPQ_{8-10} score. Furthermore, a significant negative coefficient was found between brushing frequency and fluorosis (TFI≥4, $p<0.01$). Additionally, Table 6 presents the odds ratio obtained in the GSEM analysis of CPQ_{11-14} score and caries and fluorosis status. Children with caries were more likely to have poor OHRQoL than children without lesions [ICDAS 1-3: OR=1.93, (95% CI 1.79-2.07, $p<0.001$), ICDAS ≥4: OR=2.18, (95% CI 2.13-2.24, $p<0.001$)]. Furthermore, high levels of dental fluorosis (TFI ≥4) were associated with poor CPQ_{11-14} score [OR=2.39, (95% CI 2.12-2.69, $p<0.001$)]; low brushing frequency (<2/day) also was associated with poor CPQ_{11-14} score [OR=2.04, (95% CI 1.21-3.44, $p<0.01$)] and boys showed a lower probability of experiencing poor CPQ_{11-14} score than girls [OR=0.79, (95% CI 0.78-0.80, $p<0.001$)]. No association was found between low fluorosis levels (TFI 1-3, $p=0.508$) and CPQ_{11-14} score. Regarding tooth brushing frequency, an association was found with high fluorosis categories (TFI ≥4); children who brushed fewer than two times a day showed a lower probability of high levels of fluorosis [OR=0.81, (CI 0.70-0.93, $p=0.01$)]. No significant association was found between brushing frequency and low fluorosis categories (TFI 1-3) or dental caries.

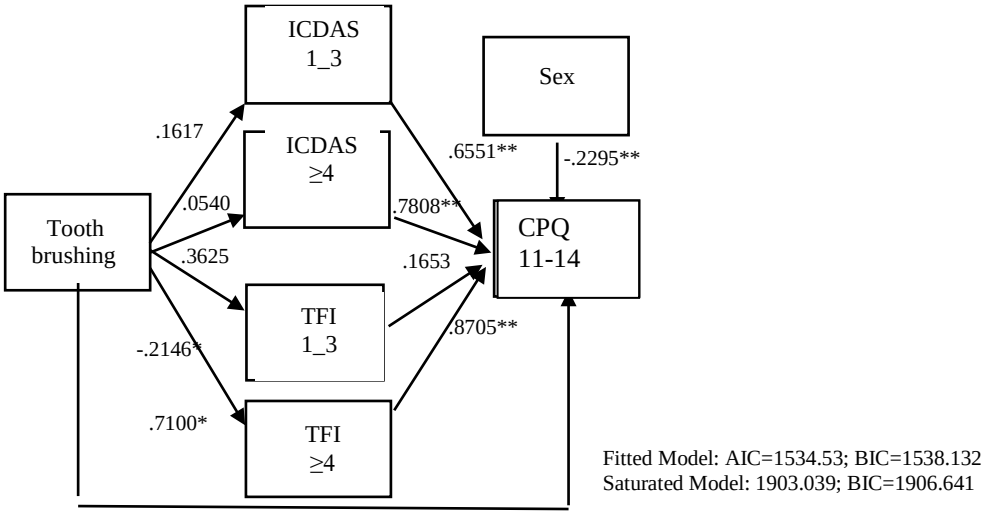

Figure 3. Graphical representation of the model for children´s 11-12-years-old Quality of Life. Results from structural equation model (Logistic regression) coefficients. *p<.01, **p<.001. Reference Categories: Tooth brushing frequency <2/day, ICDAS=0, TFI=0, Sex=females. ICDAS= International Caries Detection and Assessment System, TFI= Thylstrup and Fejerskov Index. AIC: Akaike´s information criterion; BIC: Bayesian information criterion.

Table 6. Odds ratios (OR) of the generalized structural equations model for oral health-related quality of life (CPQ_{11-14}) and dental caries, dental fluorosis, tooth brushing frequency and sex in 11-12-year-old schoolchildren

Variables	OR [a] (95% CI)	p
Dental Caries (ICDAS II score)		
ICDAS II 1-3	1.93 (1.79 – 2.07)	<0.001
ICDAS II ≥4	2.18 (2.13 – 2.24)	<0.001
[c] Dental fluorosis (TFI)		
TFI 1-3	1.18 (0.72 – 1.92)	0.508
TFI ≥4	2.39 (2.12 – 2.69)	<0.001
[d] Sex (male)	0.79 (0.78 – 0.80)	<0.001
[e] Tooth brushing frequency <2/day	2.04 (1.21 – 3.44)	<0.01

[a] CI= confidence interval. Reference: [b] ICDAS=0 (permanent teeth), [c] dental fluorosis TFI =0, [d] sex = female, [e] tooth brushing frequency≥2/day.

Discussion

In these schoolchildren the presence of carious lesions was associated with a negative impact on quality of life. The association between caries and quality of life has been reported in other groups of children in Mexico and in Latin America [33, 38]. For example, Aguilar-Díaz et al. [27] found in schoolchildren in Northern Mexico that high caries indices were associated with deterioration in quality of life, just as in Brazilian schoolchildren [39]. Our results showed that presence of caries in primary and permanent dentition (ICDAS ≥4) in schoolchildren 8-10-year-old was high. It is possible that carious lesions are causing pain or discomfort, with a high percentage reported having oral symptoms (51.2%). More than half of the 11-12-year-old also had oral symptoms. A similar association was found in African-Americans in Detroit, Michigan [40]. However, other studies have not found an association between caries experience and quality of life, such as Nigerian 11 to 14 year-olds [7]; this counterintuitive result may have been due to low caries experience. The latter prevalence of caries was under 10%.

The experience of dental fluorosis also offered interesting associations. In 11-12-year-old children, those with higher indices of fluorosis (TFI≥4) experienced a negative impact on OHRQoL compared to those without significant fluorosis. The effect size of dental fluorosis in the global and in the domains of the CPQ_{11-14} were between small and medium size [41]. More than 60% of the children in the group with high dental fluorosis scores (TFI≥4) showed global CPQ_{11-14} scores and its domains above the mean of those children without dental fluorosis. This effect was non-negligible. The main sources of fluoride in the community are recognized; therefore, attention should be paid to reducing the expose to this element in young children.

A study in Chinese children found that dental fluorosis resulted in a negative impact on the emotional and social well-being domains of CPQ [6]. Other studies in children ages 8 to 13 mentioned that as the degree of fluorosis increased, the negative impact on oral health also worsened [27]. The initial categories of TFI are manifested as a slight whitish appearance. In the more severe categories brown spots are frequently present or even loss of enamel, forming pits. Changes associated with moderate and

severe fluorosis more likely explain the negative effect of fluorosis on the OHRQoL in the aforementioned domains.

In the younger age group, 8-10-year-old, no association was identified between dental fluorosis and OHRQoL, inconsistent with findings in the older schoolchildren. Failure to identify a negative impact of fluorosis in the younger age group may be attributed to more severe forms of fluorosis in older children. However, it is also possible that with increasing age and entering the pubertal age, tweens become more sensitive to their physical appearance; smiling with anterior teeth affected by apparent fluorosis may be embarrassing, producing a negative impact on quality of life. Such links may not be experienced at earlier ages [42].

The GSEM analysis showed an association between low tooth brushing frequency and the more advanced, cavitated lesions (ICDAS≥4) in the 8-10-year-old children. The use of fluoridated toothpaste as a preventive caries strategy has been established for several decades [43]. However, no association was detected with non-cavitated lesions, thus suggesting that more accurate information is required to identify the role of fluoride toothpaste in early carious lesions in areas with above-optimal naturally fluoridated water. A study performed in the Netherlands did not detect difference in the prevalence of non-cavitated lesions between participants in fluoridated and non-fluoridated communities; nevertheless, lesion progression from non-cavitated to cavitated was lower in the fluoridated areas [44]. A study performed in African-Americans in the US did not find an association between oral hygiene habits and non-cavitated lesions; however, oral hygiene was associated with the number of surfaces showing cavitated lesions [40]. This is consistent with the findings of the present study. Our results indicated that lower tooth brushing frequency was associated with a negative impact on OHRQoL. A study conducted in China on 12-year-old children revealed that participants who brushed fewer than twice a day had a higher negative impact on OHRQoL, compared to those brushing more frequently [6]. Moreover, preschoolers in Iran who brushed their teeth fewer than once a day had a negative impact on OHRQoL [45]. It is likely that those children who have a better attitude towards oral health also have a higher frequency of tooth brushing and (they or their caregivers) may take better care of their oral

health; the specific mechanisms for these factors leading to a positive impact on OHRQoL remain to be fully established.

In the present study about two-thirds of the children had an impact on their quality of life in association with oral conditions. It was also found that more than half had a negative impact on their emotional state. These results are consistent with more than half of the participants considering themselves as not having good oral health. This aspect is important because of the emotional vulnerability of children in these age groups, thus reinforcing the importance of providing dental care services to protect oral health at this vulnerable age. Other reports have substantiated this relationship. For example, a report from Brazil showed impact on the oral health of 88.7% of schoolchildren ages 11 and 12, mainly experienced as chewing difficulties [46]. Furthermore, an association between eating problems and a negative impact on OHRQoL was detected in Spanish children ages 6 to 12 [47]. A rather innovative perspective was afforded by the GSEM analysis, which showed that tooth brushing was associated both directly with CPQ score, and also indirectly through caries and fluorosis. Oral hygiene practices more likely are markers of attitudes towards oral health. Sex in older children was associated with OHRQoL, with girls having a higher impact on OHRQoL. These aspects emphasize the multidimensional character of OHRQoL, where not only the physical dimension plays a role.

One limitation of the present study is its cross-sectional design, which hampers the identification of the temporal relationship between variables studied; however, it is a strength that the oral health conditions of each child were evaluated at the time the OHRQoL questionnaire was administered. Extrapolating data from this study group to other Mexican children should be done with caution because potential differences in socio-cultural factors may moderate the assessments by children using OHRQoL. Quality of life is a broad multidimensional concept that includes physical, psychological and social domains; it is the result of individual and group perception. In the present study physical aspects were evaluated utilizing finely graded assessments of caries and dental fluorosis. However, other dimensions were not assessed; for instance, child's self-esteem, child's attitudes towards oral health, caregiver's perception/attitudes regarding child oral health, or access to dental services.

In conclusion, we identified an association between caries, dental fluorosis and OHRQoL, in young age population groups, targeting children living in areas with naturally fluoridated at above-optimal levels. For these Mexican groups, some of the risk factors are related to lifestyle and the environment in which they live. Policy makers and health care workers in the private and public sectors should consider that some oral conditions have in fact an impact on the quality of life of children.

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Compliance with Ethical Standards

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Conflict of Interest: The authors declare that they have no conflict of interest.

Ethical approval: All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards.

Informed consent: Informed consent was obtained from all individual participants included in the study.

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