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Pathway analysis between dental caries and oral health-related quality of life in the transition from childhood to adolescence: a 10-year cohort study

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Abstract

Purpose To evaluate the direct and indirect pathways between cavitated carious lesions and oral health-related quality of life (OHRQoL) during the transition from childhood to adolescence.

Methods A prospective cohort study followed an initial sample of 639 children (one to five years old), in southern Brazil for ten years. In addition to the baseline (T1), two subsequent reassessments were conducted after seven (T2) and ten years (T3). OHRQoL was measured through the Early Childhood Oral Health Impact Scale (ECOHIS) and Child Perceptions Questionnaire (CPQ8-10 and CPQ11-14), according to the age group. Dental caries was evaluated using the International Caries Detection and Assessment System (ICDAS) in the three waves. Socioeconomic variables and other factors related to oral health (frequency of toothbrushing and toothache) were also collected. Structural equation modeling was used to estimate the direct and indirect effects among the variables over ten years.

Results A total of 449 and 429 children were reevaluated at T2 and T3 (positive response rates of 70.3% and 67.1%, respectively). Dental caries in T1 and T2 directly predicted the occurrence of a worse OHRQoL in the respective follow-up periods. Dental caries at T3 indirectly predicted a worse OHRQoL (T3), via toothache. Dental caries at T1 and T2 directly predicted the occurrence of dental caries at T3, while a worse OHRQoL at T2 directly predicted a worse OHRQoL at T3.

Conclusion Dental caries negatively impacts, directly and indirectly, the OHRQoL from early childhood to adolescence.

Keywords Dental caries · Longitudinal studies · Oral health · Quality of life · Structural equation models

Introduction

Dental caries remains an alarming disease, to the point that World Health Organization (WHO) considers it a major public health problem worldwide, with prevalence values in children varying from 60 to 90% in developing countries [1]. This condition is usually aggravated in regions with high levels of social vulnerability, where social barriers contribute to the development of inequities in oral health [2]. Dental caries is determined by biological, psychosocial, behavioral, and environmental factors [3], and it can provoke not only oral symptoms but also more complex aspects, such as the negative impact on Oral Health-Related Quality of Life (OHRQoL) of affected children and their families [4].

OHRQoL is defined as a construct that represents the individual's subjective perception of the impact of oral disorders and diseases on their physical, emotional, social, and psychological well-being [5]. Clinical conditions, such as the presence of untreated dental caries in children, are responsible for triggering a worse OHRQoL [4]. This is because children with this condition tend to report toothache, problems during eating and sleeping, and changes in behavior, which are closely related to a worsening of self-perceived oral health [4]. In addition, other factors also have a strong association with OHRQoL, such as the family's socioeconomic condition,

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which influences their ability to respond to these adverse conditions [6].

Previous studies have investigated the direct and indirect effects of predictive factors for OHRQoL in different populations [7–11]. A prospective cohort with three years of follow-up involving university students confirmed that OHRQoL and self-perceived oral health were direct and indirect predictors of OHRQoL in the follow-up [8]. Other investigations involving adolescents observed that worse clinical and socioeconomic conditions were also directly and/or indirectly associated with worse OHRQoL [7, 9–11]. However, these results belong to cross-sectional and longitudinal studies with short evaluation periods, without addressing factors that could impact the OHRQoL since the early childhood. In this sense, for the authors' knowledge, this is the first study investigating the impact of variables on OHRQoL in adolescence that also included socioeconomic and clinical variables collected in early childhood for a long period of follow-up.

According to the World Health Organization (WHO), the expression "child" is used to refer to a human being at the beginning of its development, covering individuals between zero and nine years old, while early childhood corresponds to the age group between zero and five years. Furthermore, the chronological limits in adolescence are defined by the ages between ten and 19 years old [12]. In this context, the passage from childhood to adolescence is a dynamic phase of transition and biopsychosocial development. In this period, changes inherent to the age group favor the adoption of changing feelings and sensations, due to behavioral instability [13]. Understanding the different pathways between predictors and OHRQoL in this transition period between childhood and adolescence can be important for the elaboration of an epidemiological profile regarding the needs of this population. This information can be obtained through a Structural Equation Modeling (SEM) analysis, which aims to examine the structure of interrelationships expressed in a series of equations and describe all associations, direct and indirect, between the constructs involved in the analysis [14]. Therefore, we aimed to evaluate the direct and indirect pathways between dental caries and OHRQoL throughout childhood to adolescence during ten years of follow-up. We hypothesized that dental caries directly and negatively affects OHRQoL through associations influenced by different factors, such as socioeconomic, demographic, and behavioral variables.

Methods

Ethical issues

This cohort study was approved by the Committee for Ethics in Research of School of Dentistry, Federal University of Santa Maria (UFSM) (Protocol Number 54257216.1.0000.5346). All parents or legal guardians signed a written consent form, and all literate participants signed an informed assent form. This study is reported according to STROBE (Strengthening the Reporting of Observational Studies in Epidemiology) guidelines [15].

Study design and participants

This study is a prospective cohort with ten years of follow-up, conducted in Santa Maria, a city with 261,031 inhabitants in southern Brazil. The first evaluation occurred in 2010 during National Children's Vaccination Day. In this year, the city had 27,520 children up to five years of age. The initial sample comprised 639 children aged one to five years, who were systematically selected from all 15 municipal health centers with dental chairs, equally distributed in the eight administrative regions of the city. For every five children in the vaccination queue, the first one was invited to participate in the study. If the child did not meet the eligibility criteria or the parents did not consent to their participation, the next child in line was invited to participate. Further details regarding the methodology applied have been published elsewhere [16, 17].

At baseline, all children from one to five years old who attended health centers in the city on the National Children's Vaccination Day were considered able to participate in the study. In contrast, children previously diagnosed with any degree of physical or mental disability were excluded from the study.

Follow-up assessment

After 2010, three further evaluation phases were conducted in 2012, 2017, and 2020, respectively. However, only 2010 (T1), 2017 (T2), and 2020 (T3) evaluations were considered in this study due to the participants' tooth eruption chronology (2010: primary dentition, 2017: mixed dentition, and 2020: permanent dentition). Exceptionally, T3 data collection was temporarily interrupted due to the occurrence of the COVID-19 pandemic [18]. Therefore, there was a six-month pause between the beginning and the end of the evaluation, which started in November 2019 and ended in January 2021. The age of participants in T2 and T3 ranged from 8 to 12 years old and 11 to 15 years old, respectively.

Regarding the recruitment strategies, all participants evaluated at T1 were contacted again and invited to participate in the other reassessments. Initially, the researchers tried to contact the participants through telephone calls, in order to update the participant's data and schedule the reevaluation at the clinic of the Dental School. Other children were also evaluated in a school environment, by obtaining lists of students enrolled in public schools in the city. And finally,

when the other strategies were inefficient, the participants were reassessed in their homes. If necessary, individuals and family members were contacted through social media, such as Facebook and WhatsApp. During the COVID-19 pandemic, all schools suspended their face-to-face classes and participants who had not been assessed yet, were reevaluated in their homes.

Oral health-related quality of life

The participants' OHRQoL was measured using different instruments according to the age group in each assessment. All questionnaires were answered through face-to-face interviews with previously trained examiners. In this sense, the interviewer was responsible for reading the questions directly to the interviewee. The interviewee would then provide their answers, and the interviewer would record these responses on the corresponding form.

At T1, parents or legal guardians responded to the Brazilian version of the Early Childhood Oral Health Impact Scale (ECOHIS) [19]. This questionnaire consists of 13 questions divided into two sections: the child impact section (child symptoms, function, psychological and self-image/social interaction domains) and the family impact section (parental distress and family function domains). Answers were measured on a 6-point Likert scale, ranging from 0 to 5 (0 – never; 1 – Hardly ever; 2 – Occasionally; 3 – Often; 4—Very often; and 5 – Do not know). The final score is calculated by adding all the items and the total result ranges from 0 to 52 points.

At T2 and T3, participants answered the Brazilian version of the Child Perception Questionnaire (CPQ8-10) [20] and the Brazilian short form of the Child Perceptions Questionnaire 11–14 (CPQ11-14) [21], respectively. CPQ8-10 consists of 25 questions and the short version of CPQ11-14 has 16 questions. Both questionnaires are subdivided into four domains: oral symptoms, functional limitations, emotional well-being, and social well-being. Answers were measured on a 5-point Likert scale, ranging from 0 to 4 (0 – Never; 1 – Once or twice; 2 – Sometimes; 3 – Frequently; and 4 – Every day/Almost every day). The final score is calculated by adding all the items and the total result ranges from 0 to 100 points for CPQ8-10 and 0 to 64 points for CPQ11-14.

For all questionnaires, higher scores indicate a higher negative impact of oral health problems on the OHRQoL of children and their families. All the analyses considered the overall scores of the questionnaires used.

Dental caries

Dental caries was measured in the three waves by trained and calibrated examiners. The procedures for training and calibration processes standardized by the World Health Organization for research in oral health were considered in our study [22]. Further details on the training and calibration process were previously published [16, 23]. In total, 15, 4, and 7 examiners conducted clinical examinations at T1, T2, and T3, respectively. In all evaluations, Kappa statistics (inter and intra-examiner) were higher than 0.7, considered substantial agreement (0.61–0.80) [24].

Dental caries was assessed through visual inspection, with the aid of plane dental mirrors and periodontal probes (CPI; "ball point"), using the International Caries and Detection Assessment System (ICDAS) [25]. At T1, clinical examinations were conducted on dental chairs at health centers. In subsequent reassessments, examinations were performed in a clinical, school, or home environment. Through conventional illumination, all teeth were cleaned, and the surfaces were evaluated, first, wet, and then air-dried or with gauze compress. The dental caries assessment process was standardized between the three assessments, regardless of the location of the clinical examination. After the evaluation, all participants received individualized oral hygiene instructions and the offer of free dental treatments at the Dental School.

For data analysis, the prevalence of cavitated carious lesions at T1, T2, and T3, corresponding to ICDAS scores 3, 5, and 6, was considered. In this sense, surfaces with ICDAS stages 0, 1, 2, and 4 were classified as free of cavitated carious lesions.

Covariates

Demographic, socioeconomic variables, and factors related to oral health were collected over the course of T1 to T3. At T1, parents or legal guardians answered a structured questionnaire providing a series of information, including the child's sex (boy and girl) and age (in years), household income, maternal education, and their children's toothbrushing frequency. Among the variables collected in the other reassessments, the variables of household income collected in T2 and T3, the frequency of toothbrushing in T2, and the presence of toothache in T3 were considered for the construction of the model. In the two reevaluations, the children answered the questionnaire, and, in case of doubt, the parents were contacted to answer.

Maternal education was collected from the number of years of study and dichotomized into "≥ 8 years of formal education", which corresponds to primary school in Brazil, and "< 8 years of formal education". Household income was collected in Reais (R$—official Brazilian currency—R$ 5.62 was equivalent to US$ 1.00 in the year 2021) from the sum of all forms of income obtained in the previous month and categorized in quartiles from Q1 (Lowest) to Q4 (Highest). The frequency of toothbrushing was assessed by the number of times the participants brushed their teeth a day

(0 – Do not brush; 1 – 1 × a day; 2 – 2 × a day; 3 – 3 × a day or more). Finally, the presence of toothache was questioned in relation to the last 12 months (0 – No and 1 – Yes) [26].

Statistical analyses

Data analysis was performed using the statistical software STATA 14.0 (Stata Corporation). Descriptive analyzes demonstrated the characteristics of the sample evaluated at T1, T2, and T3. The main variables of interest (outcomes) were the OHRQoL and cavitated carious lesions in the three evaluation periods. The comparison between subjects and dropouts was assessed using the Chi-square test (qualitative variables) and the T-test (quantitative variables). Individuals evaluated before and during the COVID-19 pandemic at T3 were also compared for main characteristics. In instances of observed differences, a sensitivity analysis (Bootstrap with 500 replications) was performed to assess whether these differences could impact the results. The analyzes were performed considering the weight of the sample (Stata's "svy" command).

The pathways between dental caries and OHRQoL were analyzed through structural equation modeling (SEM). The analysis was conducted based on the conceptual theoretical model of social determinants in oral health created by Watt and Sheiham [27]. Several variables were tested until the model reached an adequate adjustment value and a degree of limiting saturation. SEM analysis was composed only by the structural model, which estimates the magnitude of the effects (total, direct, and indirect) among the evaluated variables (pathways analyses). The effect of standardized coefficients (SCs) was interpreted as small (SC about 0.10), medium (SC about 0.30), and strong (SC > 0.50) [14]. The Maximum Likelihood with Missing Values (MLMV) estimation method was used in all models. The goodness of fit was measured using the following Modification Indices (MI): Root Mean Square Error of Approximation (RMSEA); and Comparative Fit Index (CFI); Tucker-Lewis Index (TLI). The RMSEA value < 0.05 and CFI and TLI > 0.90 suggests an adequate fit [14]. Modification indices (MI) of values > 10 were examined and introduced if supported by theory or empirical results of prior knowledge. Non-significant pathways that do not contribute to the model were removed step by step if P > 0.20 and SC < 0.10 (rule of parsimony).

Results

A total of 449 and 429 children were reevaluated at T2 and T3, representing 70.3% and 67.1% of the 639 individuals assessed at the beginning of the cohort, respectively. Losses in the follow-up occurred due to the impossibility of contact due to a change of address and/or telephone (n = 181 in T2 and n = 203 in T3) or by refusal of legal guardians and/or participants (n = 9 in T2 and n = 7 in T3) (Fig. 1). No significant differences were found for most of the sample's characteristics between those assessed and dropouts (P > 0.05). However, the reassessed participants were from low-income families. A sensitivity analysis (Bootstrap) demonstrated that this difference did not influence the results. Regarding subjects assessed before and during the COVID-19 pandemic (at T3), there were significant differences only for toothbrushing frequency, however, the Bootstrap analysis

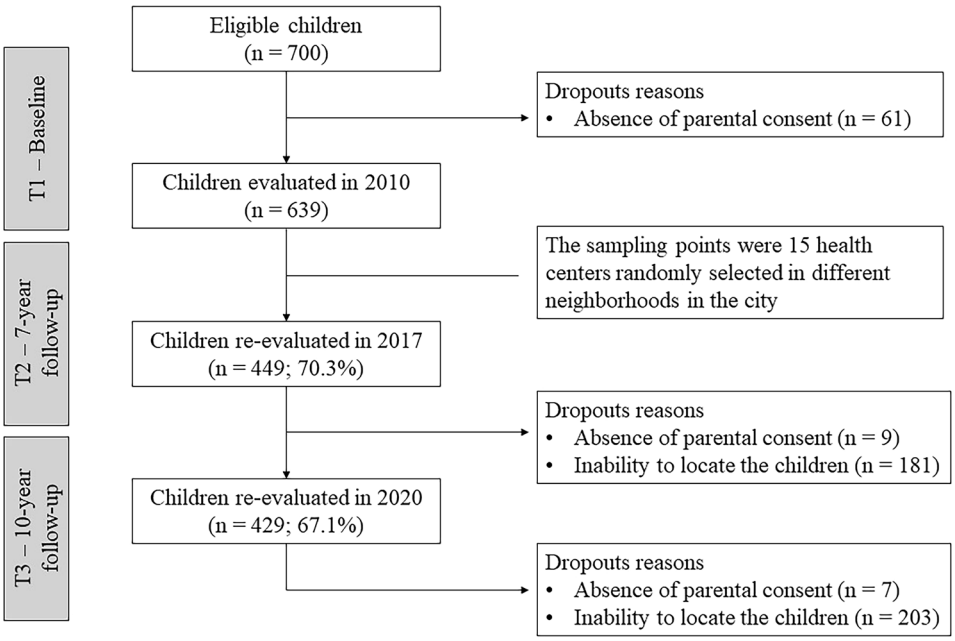

Fig. 1 Flowchart of participants in the 3 different phases of cohort follow-up

showed that this difference did not affect our findings. A power calculation for pathway analysis was calculated. Considering an alpha error of 0.05%, 102 degrees of freedom, a sample size of 639 participants, and an RMSEA value of 0.5 in the initial model and 0.4 in the final model, the model presented a power of 70%.

Table 1 shows the characteristics of the analyzed participants at T1, T2, and T3. In the three evaluations, the sample showed a balance between girls and boys, and the mean age was 2.75 [0.05 standard error (SE)], 9.95 (SE 0.05), and 12.58 (SE 0.08) years. Most participants' mothers had formal education (≥ 8 years) in the three waves. Most of the participants belonged to the second quartile of household income in T1 and T2 (medium lowest), and in T3 started to belong to the first quartile (lowest). The mean overall of ECOHIS, CPQ8-10, and CPQ11-14 scores was 2.36 (SE 0.30), 10.57 (SE 0.69), and 10.64 (SE 0.63), while the proportion of teeth with cavitated carious lesions was 38.4%, 50.7%, and 30.6% at T1, T2, and T3, respectively. Finally, most participants had a toothbrushing frequency ≥ 3 × a day and no toothache in the last 12 months during the three assessment times.

The final structural model with the best data fit is shown in Table 2 and Fig. 2. The pathways that did not show statistical significance were removed one by one in stages. Dental caries in T1 and T2 directly predicted the occurrence of a worse OHRQoL in the respective follow-up times. Dental caries at T3 indirectly predicted a worse OHRQoL (T3). Furthermore, dental caries at T1 and T2 directly predicted the occurrence of dental caries at T3, while a worse OHRQoL at T2 directly predicted a worse OHRQoL at T3. Toothache directly predicted a worse OHRQoL at T3. Socioeconomic, demographic, and behavioral variables, such as household income, maternal education, age, and frequency of toothbrushing, also played important roles in the model. Household income directly predicted the occurrence of dental caries in the three follow-up times, toothache in T3, and worse OHRQoL in T2. Age directly predicted the development of dental caries at T1, T2, and T3. Finally, maternal education at T1 and frequency of toothbrushing at T2

Table 1 Characteristics of the followed participants at the baseline (n = 639), at T2 (n = 449), and T3 (n = 429)

Variables	T1 (Baseline)[*,†]	T2 (7 years of follow-up)[*,†]	T3 (10 years of follow-up)[*,†]
Sex [n (%)]	322 (49.8)	220 (49.7)	209 (49.8)
Boys	317 (50.2)	229 (50.3)	220 (50.2)
Girls			
Age [mean (SE)[a]]	2.75 (0.05)	9.95 (0.08)	12.58 (0.08)
Maternal education [n (%)]	357 (54.3)	322 (74.6)	285 (69.6)
≥ 8 years of formal education	275 (45.7)	120 (25.4)	110 (30.4)
< 8 years of forma education			
Household income in R$[b] [n (%)]	137 (19.8)	115 (25.2)	110 (29.2)
Lowest (1st quartile)	172 (33.4)	110 (27.0)	79 (23.4)
Medium lowest (2nd quartile)	170 (28.8)	103 (21.6)	108 (25.5)
Medium highest (3rd quartile)	123 (18.0)	107 (26.2)	77 (21.9)
Highest (4th quartile)			
OHRQoL[c] [mean (SE)]	2.36 (0.30)	10.57 (0.69)	10.64 (0.63)
Cavitated carious lesions[d] [n (%)]			
Without	408 (61.6)	223 (49.3)	300 (69.4)
With	231 (38.4)	226 (50.7)	128 (30.6)
Frequency of toothbrushing [n (%)]	3 (0.1)	19 (3.2)	11 (1.6)
≥ 3 × a day	145 (25.7)	66 (11.2)	61 (13.4)
2 × a day	212 (35.2)	175 (39.9)	177 (38.7)
1 × a day	232 (39.0)	188 (45.7)	180 (46.3)
Do not brush			
Toothache (last 12 months) [n (%)]	398 (81.7)	223 (49.8)	297 (70.4)
No	75 (18.3)	225 (50.2)	130 (29.6)
Yes			

[*]Taking into account the sampling weight

[†]Unmatched values due to missing data

[a]SE, standard error

[b]R$—official Brazilian currency—R$ 5.62 was equivalent to US $ 1.00 in the year 2021

[c]OHRQoL – ECOHIS (T1), CPQ8-10 (T2), and CPQ11-14 (T3)

[d]Cavitated carious lesions – ICDAS 3, 5, and 6

Table 2 Structural equation model among variables in the initial and final model

Pathway	Standardized coefficients	
	Initial model	Final model
Cavitated carious lesions (T1)		
Frequency of toothbrusing (T1)	0.04 (p = 0.24)	0.04 (p = 0.25)
Household income (T1)	−0.12 (p < 0.01)	−0.12 (p < 0.01)
Sex (T1)	−0.06 (p = 0.09)	−0.06 (p = 0.09)
Maternal education (T1)	0.10 (p < 0.05)	0.10 (p < 0.05)
Age (T1)	0.35 (p < 0.01)	0.35 (p < 0.01)
OHRQoL (T1)		
Cavitated carious lesions (T1)	0.22 (p < 0.01)	0.22 (p < 0.01)
Household income (T1)	−0.07 (p = 0.13)	−0.07 (p = 0.13)
Sex (T1)	−0.01 (p = 0.83)	–
Maternal education (T1)	0.04 (p = 0.38)	0.04 (p = 0.39)
Age (T1)	0.07 (p = 0.10)	0.07 (p = 0.10)
Cavitated carious lesions (T2)		
Cavitated carious lesions (T1)	0.14 (p < 0.05)	0.14 (p < 0.01)
Frequency of toothbrushing (T2)	0.12 (p < 0.05)	0.11 (p < 0.01)
Household income (T2)	−0.12 (p < 0.05)	−0.13 (p < 0.01)
Sex (T1)	0.03 (p = 0.40)	–
Age (T1)	−0.15 (p < 0.01)	−0.15 (p < 0.01)
OHRQoL (T2)		
Cavitated carious lesions (T1)	−0.02 (p = 0.59)	–
OHRQoL (T1)	0.02 (p = 0.72)	–
Cavitated carious lesions (T2)	0.19 (p < 0.01)	0.19 (p < 0.01)
Frequency of toothbrushing (T2)	0.14 (p < 0.01)	0.14 (p < 0.01)
Household income (T2)	−0.18 (p < 0.01)	−0.18 (p < 0.01)
Sex (T1)	0.04 (p = 0.30)	0.04 (p = 0.29)
Cavitated carious lesions (T3)		
Cavitated carious lesions (T1)	0.12 (p < 0.05)	0.12 (p < 0.05)
Cavitated carious lesions (T2)	0.18 (p < 0.01)	0.19 (p < 0.01)
Frequency of toothbrushing (T3)	0.02 (p = 0.55)	–
Household income (T3)	−0.15 (p < 0.05)	−0.15 (p < 0.01)
Sex (T1)	−0.08 (p = 0.07)	−0.08 (p = 0.05)
Age (T1)	−0.09 (p = 0.04)	−0.09 (p < 0.05)
OHRQoL (T3)		
Cavitated carious lesions (T1)	−0.03 (p = 0.50)	–
Cavitated carious lesions (T2)	−0.02 (p = 0.51)	−0.02 (p = 0.51)
OHRQoL (T2)	0.32 (p < 0.01)	0.32 (p < 0.01)
Cavitated carious lesions (T3)	−0.04 (p = 0.35)	−0.04 (p = 0.34)
Toothache (T3)	0.23 (p < 0.01)	0.23 (p < 0.01)
Household income (T3)	−0.01 (p = 0.73)	–
Sex (T1)	0.14 (p < 0.01)	−0.14 (p < 0.01)
Toothache (T3)		
Cavitated carious lesions (T3)	0.19 (p < 0.01)	0.20 (p < 0.01)
Household income (T3)	−0.22 (p < 0.01)	−0.23 (p < 0.01)
Cavitated carious lesions (T2)	0.05 (p = 0.25)	0.05 (p = 0.23)
Maternal education (T1)	−0.04 (p = 0.36)	−0.04 (p = 0.33)
Sex (T1)	0.01 (p = 1.00)	–
Age (T1)	−0.07 (p = 0.10)	−0.07 (p = 0.10)
Frequency of toothbrushing (T1)		
Household income (T1)	0.02 (p = 0.55)	–

Table 2 (continued)

Pathway	Standardized coefficients	
	Initial model	Final model
Sex (T1)	−0.04 (p = 0.27)	−0.04 (p = 0.27)
Maternal education (T1)	0.12 (p < 0.05)	0.10 (p < 0.01)
Age (T1)	−0.26 (p < 0.01)	−0.26 (p < 0.01)
Frequency of toothbrushing (T2)		
Frequency of toothbrushing (T1)	0.11 (p < 0.05)	0.11 (p < 0.05)
Household income (T2)	−0.01 (p = 0.77)	–
Maternal education (T1)	0.11 (p < 0.05)	0.12 (p < 0.01)
Frequency of toothbrushing (T3)		
Frequency of toothbrushing (T2)	0.19 (p < 0.01)	0.19 (p < 0.01)
Household income (T3)	−0.12 (p < 0.05)	−0.12 (p < 0.05)
Sex (T1)	−0.15 (p < 0.01)	−0.15 (p < 0.01)
Maternal education (T1)	−0.09 (p = 0.07)	−0.09 (p = 0.06)
Age (T1)	−0.02 (p = 0.53)	–
Household income (T1)		
Maternal education (T1)	−0.43 (p < 0.01)	−0.43 (p < 0.01)
Household income (T2)		
Household income (T1)	0.42 (p < 0.01)	0.42 (p < 0.01)
Maternal education (T1)	−0.23 (p < 0.01)	−0.23 (p < 0.01)
Household income (T3)		
Household income (T2)	0.60 (p < 0.01)	0.60 (p < 0.01)
Model Fit		
RMSEA (90% CI)	0.050 (0.040–0.060)	0.043 (0.033–0.052)
CFI	0.91	0.92
TLI	0.82	0.87

T1 baseline; *T2* 7-y follow-up, *T3* 10-y follow-up, *RMSEA* Root Mean Square Error of Approximation, *CI* Confidence interval, *CFI* Comparative Fit Index, and *TLI* Tucker-Lewis Index

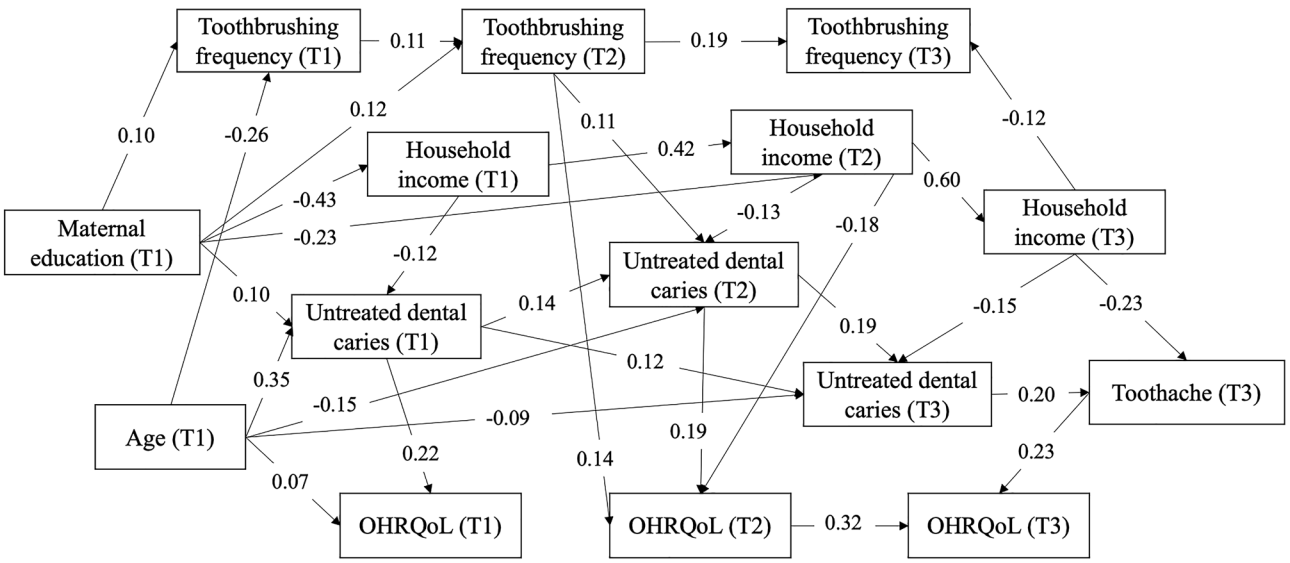

Fig. 2 Significant pathways of the final structural model

directly predicted the occurrence of dental caries at T1 and T2, respectively.

Table 3 shows the direct, indirect, and total effects between dental caries and OHRQoL during the three-time follow-up in the parsimonious SEM model. The highest significant total effects observed correspond to the effect of dental caries in T2 on a worse OHRQoL in T2 (SC = 4.05) and dental caries in T1 on a worse OHRQoL in T1 (SC = 2.02), and both had no indirect effects on OHRQoL. A direct effect was observed from dental caries at T1 to dental caries at T2 (SC = 0.14) and T3 (SC = 0.11). Dental caries (from T2 to T3) and a worse OHRQoL (from T2 to T3) showed only significant direct effects (SC = 0.17 and SC = 0.26). In addition, dental caries at T1 had a significantly greater indirect effect on worse OHRQoL at T2 (SC = 0.59) via dental caries (T2), as well as dental caries at T2 had a significantly indirect effect on worse OHRQoL at T3 (SC = 1.30), via OHRQoL (T2) and dental caries (T3). Finally, dental caries at T3 had a significant indirect effect on worse OHRQoL at T3 (SC = 0.85), via toothache (T3).

Discussion

This study explored the direct and indirect pathways between dental caries, associated factors, and OHRQoL during a ten-year follow-up, addressing the transition from childhood to adolescence. It was observed that the occurrence of dental caries in T1 and T2 directly predicted a worse OHRQoL in the respective follow-up times, as well as the development of dental caries in T3. Dental caries at T3 indirectly predicted a worse OHRQoL at T3 via toothache. Finally, a worse OHRQoL in T2 directly predicted a worse OHRQoL in T3. These results confirm the hypothesis that dental caries, directly and indirectly, affect the OHRQoL of individuals.

The statistical approach by SEM allows the estimation of variables that present direct and indirect effects in the outcome, through the formulation of complex causal pathways [14]. Studies conducted recently investigated the pathways capable of leading different predictors to affect the OHRQoL in adolescents and college students. Among the results observed, baseline OHRQoL and self-rated oral health had a direct effect on follow-up OHRQoL [8]. However, the effect of clinical variables, such as dental caries, did not reach a consensus between studies. Some authors found a direct effect between dental caries and OHRQoL [9, 10], while others observed an indirect effect, mediated by psychosocial variables [11], and no effect [8]. However, most studies had a cross-sectional design or had short follow-up times. This is the first study investigating the impact of variables on OHRQoL in adolescence that also included socioeconomic and clinical variables collected in early childhood.

The occurrence of dental caries in both primary and permanent teeth, collected in all evaluation periods, had a direct or indirect effect on the adolescents' OHRQoL. This result is in line with the consolidated literature regarding the consequences of dental caries, such as pain and chewing problems, on the quality of life of children and adolescents

Table 3 Standardized coefficients for direct, indirect, and total effects between untreated dental caries and OHRQoL at baseline, T2, and T3

Pathways	Direct effects	Indirect effects	Total effects
From dental caries (T1) to OHRQoL (T1)	2.02*	–	2.02*
From dental caries (T1) to dental caries (T2)	0.14*	–	0.14*
From dental caries (T1) to OHRQoL (T2) Via dental caries (T2)	–	0.59*	0.59*
From OHRQoL (T1) to OHRQoL (T2)	–	–	–
From dental caries (T2) to OHRQoL (T2)	4.05*	–	4.05*
From dental caries (T1) to dental caries (T3) Via dental caries (T2)	0.11*	0.03*	0.14*
From dental caries (T2) to dental caries (T3)	0.17*	–	0.17*
From dental caries (T1) to OHRQoL (T3) Via dental caries (T2) Via OHRQoL (T2)	–	0.12	0.12
From dental caries (T2) to OHRQoL (T3) Via OHRQoL (T2) Via dental caries (T3) ➔Toothache (T3)	−0.50	1.30*	0.80
From OHRQoL (T2) to OHRQoL (T3)	0.26*	–	0.26*
From dental caries (T3) to OHRQoL (T3) Via toothache (T3)	−0.81	0.85*	0.04

T1 baseline, *T2* second follow-up, *T3* third follow-up; *p < 0.05

[4, 28]. In this sense, the observed impact accompanied the participants in their reassessment phases, clarifying that, regardless of age during the transition from childhood to adolescence, dental caries negatively impacts quality of life. However, despite the participants being offered dental treatment in our Dental School, most did not seek clinical care. Another important issue is that the negative impact of dental caries on OHRQoL was greater in early childhood (T1). A hypothesis for this result is that parents/legal guardians could exacerbate the impact experienced by their children through the ECOHIS instrument, which considers the impact of oral condition on the child's family domain [19, 29].

However, no direct effect was observed between dental caries (T3) and OHRQoL (T3). This is probably justified by the influence of the COVID-19 pandemic, which was under development during part of the T3 reassessment. A study conducted with this cohort sample identified an improvement in OHRQoL during the pandemic period [30]. It is assumed that adolescents have minimized the negative perception of the impact of their oral problems in a period full of hospital admissions and deaths due to the COVID-19 pandemic, as well as through greater family social support during this period. However, there was an indirect effect of dental caries, via toothache, on the OHRQoL, which means that only adolescents who presented dental pain due to dental caries reported a worse OHRQoL.

Dental caries at T3 was directly influenced by dental caries at T1 and T2. It is known that the presence of sociodemographic, contextual, and psychosocial determinants that are established in the lives of individuals can influence the transmission of behavioral habits and the consequent experience of dental caries [31, 32]. However, great emphasis has been placed on clinical variables related to previous experience of dental caries in the primary dentition, demonstrating a strong association with the development of the disease in the permanent dentition [32]. Previous results found significant differences in the course of the disease in a sample of children evaluated over seven years, with those who had developed carious lesions during childhood having a higher risk of developing lesions in the permanent dentition [32]. Therefore, our results confirm the intimate relationship between dental caries in both dentitions, serving both as a reinforcement of knowledge about the risk of developing caries disease, as well as an alert to the need to direct attention to preventive dental care in children.

A worse OHRQoL of children in T2 directly influenced a worse OHRQoL of adolescents in T3, representing the temporal impact of this psychosocial variable. A previous study using an SEM approach found that adolescent OHRQoL had a direct effect on better OHRQoL after three years of follow-up [33]. However, it is expected that the direction of the effect will change according to the clinical profile of the sample evaluated in each survey. In this study, the proportion of untreated dental caries increased between the first two reassessments, which justifies a worsening in OHRQoL between these observed periods. However, there was a decrease in the prevalence of carious lesions between T2 and T3, probably attributed to the change of dentitions. In addition, the OHRQoL in T1 did not influence the respective variable in the other reassessment times. It is hypothesized that this occurred because the parents acted as a proxy in measuring the OHRQoL at T1, and even though this is an approach widely accepted in the literature, there may be some difference in the perception experienced by the child [29].

Demographic (age), socioeconomic (household income and maternal education), and behavioral (frequency of toothbrushing) factors had direct effects on dental caries and OHRQoL variables. These relationships are in line with previous literature, which states that children from a poorer social background have limited access to knowledge and a greater chance of adopting behaviors that are harmful to oral health [2, 34]. However, except for age, all other variables influenced the outcomes only in their respective times, which may indicate changes in factors observed between the evaluation periods, making them unable to directly influence the evaluated outcomes.

This study has some limitations. The measurement of OHRQoL was obtained through different instruments over the three assessments, which may compromise the comparability of responses. However, it was decided to apply validated questionnaires that best fit the age group assessed, which have the common objective of reporting the quality of life of individuals. In addition, it has been demonstrated that the CPQ instrument can be applied across diverse age cohort without jeopardizing understanding or response integrity, making it a valid questionnaire for measuring OHRQoL beyond predefined age groups [35]. Second, only a few variables were selected and introduced into the analytical model. Thus, other factors that were not included in the analysis can act as indirect mediators in causal pathways. Finally, T3 was conducted during the COVID-19 pandemic. Despite studies have shown that behavioral changes occurred in this sample [36], sensitivity analyzes demonstrated that this concern did not affect our results. Furthermore, as stated above, the results of this study are supported by previous literature and this limitation is inherent to the period experienced.

On the other hand, this study has strengths that should be recognized. After ten years of follow-up, a high cohort retention rate (67.1%) was obtained with a relatively large final sample. In addition, since the sample was followed in the transition from childhood to adolescence, it is possible to establish an epidemiological profile of this age group, providing a greater understanding of clinical and psychosocial behavior in a phase full of changes and emotional instability. To make public policy evaluation and planning

possible, accurate and understandable epidemiological data that provide prevalence and disease trends over time are needed [37]. Therefore, this is what this study set out to investigate.

Conclusion

In conclusion, dental caries negatively impact, directly or indirectly, the OHRQoL of children and adolescents over time. These results highlight the impact of caries disease on the OHRQoL of children and adolescents during the transition from childhood to adolescence, serving as a warning for a greater focus on public health strategies for the treatment of this age group. Furthermore, clinicians should recognize the importance of preventing and treating caries lesions during this transitional phase and apply this information in their day-to-day professional practice, aiming to promote greater well-being and OHRQoL for their patients over time.

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Authors contribution Ms. Brondani conceptualized and designed the study, collected data, performed the statistical analyses, drafted the initial manuscript, and revised the manuscript. Ms. Knorst conceptualized and designed the study, collected data, performed statistical analyses, and revised the manuscript. Dr. Ardenghi and Dr. Mendes designed the study, coordinated, and supervised the data collection, and critically reviewed the manuscript. All authors have approved the final manuscript and agree to be accountable for all aspects of the paper.

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Declarations

Competing interests The authors have no relevant financial or non-financial interests to disclose.

Ethics approval All procedures performed in studies involving human participants were in accordance with the ethical standards of the Human Research Ethics Committee of the Federal University of Santa Maria (CAEE: 66553117.4.0000.5346, 2018), Brazil.

Consent to participate Informed consent was obtained from all individual participants included in the study.

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