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Impact of different detection criteria on caries estimates and risk assessment

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Aim: This study aimed to compare the prevalence and extent of dental caries according to the standard World Health Organization (WHO), modified WHO and International Caries Detection and Assessment System (ICDAS) criteria among 12-year-old Brazilian schoolchildren and to assess the impact of these detection criteria on the assessment of sociodemographic risk indicators for dental caries. **Methods:** This cross-sectional survey used a multistage probability sampling strategy to select a representative sample of 12-year-old schoolchildren. After tooth cleaning and drying, a single examiner recorded the presence of non-cavitated and cavitated caries lesions. A questionnaire gathered demographic and socio-economic information. Three proposed thresholds for caries detection were used: standard WHO criteria (only cavitated lesions); modified WHO criteria (active non-cavitated lesions and cavitated lesions); and ICDAS (all non-cavitated and cavitated lesions). Prevalence ratios (PR), rate ratios (RR) and 95% confidence intervals (95% CI) were estimated using survey Poisson regression analysis. **Results:** In total, 1,528 of 1,837 eligible schoolchildren participated. Caries prevalence (standard WHO, 55.23%; modified WHO, 63.33%; ICDAS, 79.82%) and decayed, missing and filled teeth (DMFT) index (standard WHO, 1.39; modified WHO, 1.95; ICDAS, 3.78) increased as the detection criteria became more sensitive. Compared with the standard WHO criteria, ICDAS had a greater impact on caries estimates, mainly in schoolchildren of higher socio-economic background. All socio-economic variables were significantly associated with dental caries, irrespective of the detection criteria. **Conclusion:** The inclusion of non-cavitated lesions impacted estimates of prevalence and extent of dental caries, mainly when ICDAS was used. No impact was observed on the association between caries and socio-economic variables.

Key words: *Dental caries, diagnosis, prevalence, risk indicators, epidemiology*

INTRODUCTION

Disease estimates depend on several factors, including accuracy and validity of measurements, detection criteria and disease definition[1]. Dental caries, as for so many other diseases and conditions, might be detected and defined in a continuum ranging from slight biochemical changes to obvious lesions. In epidemiology, constrains pertaining to time, costs and logistics often impact health-survey decisions and this is also true for oral outcomes. Historically, the World Health Organization (WHO) has recommended that caries detection should be performed at the cavity level[2], thus ignoring the presence of non-cavitated lesions. Although this criteria improves examiner reliability and is less time-consuming[3], it may underestimate caries experience, mainly in populations with low prevalence of the disease[4,5]. The notion that individuals with non-cavitated caries lesions should not be regarded as 'caries free' led to the inclusion of these lesions in epidemiological surveys. Initially, only non-cavitated enamel lesions with a chalk-like appearance (white spots) were included in the caries examination protocol, leading to the establishment of a modified WHO criteria[6–9]. In the last two decades, two detection criteria proposed the recording of all non-cavitated lesions, including active/inactive[10] and white/brown [11] lesions. However, few studies have assessed the impact of the inclusion of non-cavitated lesions on the epidemiology of caries and, most importantly, its added benefit to risk assessment.

Caries estimates are heavily dependent on the examination protocol and detection criteria used[1,12]. While the inclusion of white and opaque (active) non-cavitated lesions has an obvious effect on caries estimates, increasing it by 15–30%[7], the addition of inactive lesions has the potential to impact disease estimates even further[13,14]. Similarly, risk assessment might also be affected by examination protocols and detection criteria. Previous studies using the International Caries Detection and Assessment System (ICDAS) have shown an association between caries and soft drink consumption[15,16], visible plaque and bacterial counts[17]. However, studies using the ICDAS have failed to find associations between well-known sociodemographic factors and caries. Educational level was significantly associated with cavitated lesions, but not with non-cavitated lesions, among low-income African-Americans from Detroit (MI, USA)[18]. Similar results were observed when the ICDAS instead of the standard WHO criteria was used to assess the association between caries prevalence and sociodemographic factors in a small sample of 3- to 5-year-old children[14].

Population-based studies are warranted to ascertain the effect of the inclusion of non-cavitated lesions on the epidemiology of dental caries. Therefore, the aims of this study were to compare the prevalence and extent of dental caries according to three different detection criteria (standard WHO, modified WHO and ICDAS) among 12-year-old schoolchildren from Southern Brazil and to assess the impact of these detection criteria on the assessment of sociodemographic risk indicators for dental caries.

METHODS

Study design and sample selection

Data pertaining to 1,528 schoolchildren who participated in a cross-sectional survey in Porto Alegre, Southern Brazil, were used in the present study. Detailed information regarding the sampling strategy and sample characteristics have been previously published[19]. In brief, 12-year-old schoolchildren who were attending public and private schools were clinically examined between September 2009 and December 2010. Schoolchildren born in 1997 or 1998 who regularly attended school were considered eligible for the study. Students with special needs or undergoing fixed orthodontic treatment were excluded from the sample. A multistage probability sampling strategy was used with the primary sampling unit consisting of five geographical areas organised according to the municipal water-fluoridation system. Within each area, schools were randomly selected proportional to the number of existing public and private schools (42 schools: 33 public and nine private). Schoolchildren were randomly selected proportional to school size. A total of 1,528 schoolchildren were examined (overall response rate: 83.17%).

Data collection

Clinical examinations were conducted at the schools, with the students in a supine position, using sterile clinical mirrors and periodontal probes. Portable equipment (artificial light, air compressor and suction) was used to ensure proper conditions for clinical examination regarding humidity control and lighting. Before caries examination, schoolchildren received professional toothbrushing and flossing. A single examiner (LSA) performed caries examination and recorded whether the surfaces were sound, decayed, missing or filled. The decayed component was classified according to the presence of cavitation (cavitated or non-cavitated caries[11]) and activity (active or inactive caries[20]). Lesions were defined as follows:

- Active non-cavitated - opaque enamel with a dull-whitish surface
- Inactive non-cavitated - shiny surface with different degrees of brownish discoloration
- Active cavitated - localised surface destruction with active characteristics (dull-whitish enamel and soft dentin of a light brown color)
- Inactive cavitated - localised surface destruction with arrested characteristics (shiny, hard surfaces with different degrees of brownish discoloration).

A questionnaire was sent to the parents/legal guardians of each selected student to collect data for the risk-assessment analyses. This questionnaire gathered information on demographic and socio-economic characteristics, such as gender, mother's and father's education, socio-economic status[21], number of rooms in the house and number of people living in the house.

Reproducibility

Before the beginning of the study, the examiner underwent training by the assessment of photographs and clinical examinations. Assessment of reproducibility before and during the survey was conducted through repeated examinations on 5% of the sample. The minimal time interval between examinations was 2 days. The lowest Cohen's Kappa (unweighted) was 0.80 for the standard WHO criteria, 0.81 for the modified WHO criteria and 0.82 for ICDAS.

Data analysis

The definitions of caries prevalence and extent were based on the decayed, missing and filled teeth

(DMFT) index. Caries prevalence was defined as the percentage of schoolchildren having at least one decayed, missing or filled tooth (DMFT ≥ 1). Caries extent was defined as the sum of the number of decayed, missing and filled teeth (DMFT index). Caries prevalence and caries extent according to standard WHO criteria (only cavitated caries lesions), modified WHO criteria (active non-cavitated lesions and cavitated lesions) and ICDAS (all non-cavitated and cavitated caries lesions) were reported as mean and 95% confidence interval (95% CI).

Absolute differences were calculated for the modified WHO and ICDAS criteria in relation to the standard WHO criteria. Inflation rates were calculated by dividing the estimates obtained using the modified WHO and ICDAS criteria by those obtained using the standard WHO criteria. Absolute differences and inflation rates were calculated for caries prevalence and extent. Wald tests for linear and non-linear hypothesis testing were used to calculate *P*-values and the significance was set at 5%.

The bivariate association between the sociodemographic variables and dental caries using different detection criteria was assessed using survey Poisson regression models. Prevalence ratios (caries prevalence), rate ratios (caries extent) and their respective 95% CI were estimated and reported.

Data analysis was performed using STATA software (Stata 13.1 for Windows; Stata Corporation, College Station, TX, USA), and estimates of prevalence, extent and association were calculated taking into account the survey design, as described previously[19]. In short, a weight variable based on the probability of selection and population distribution according to gender, school type and city area was used to adjust for the potential participation bias in the population estimates.

Ethical aspects

The study protocol was approved by the Federal University of Rio Grande do Sul Research Ethics Committee (299/08) and by the Municipal Health Department of Porto Alegre Research Ethics Committee (process n° 001.049155.08.3/register n° 288). All participants and their parents/legal guardians provided written informed consent. This study was conducted in full accordance with the World Medical Association Declaration of Helsinki.

RESULTS

Caries prevalence using the standard WHO, modified WHO and ICDAS criteria, according to sociodemographic variables, are presented in *Table 1* and *Figure 1*. The inclusion of non-cavitated lesions had a great impact on caries prevalence estimates. The standard WHO criteria yielded a caries prevalence of 55.23%, which was 8.10 percentage points and 24.59 percentage points lower than the modified WHO and ICDAS criteria, respectively. These differences correspond to an inflation of 14% (inflation rate = 1.14) for the modified WHO criteria and of 44% (inflation rate = 1.44) for the ICDAS criteria when compared with the standard WHO criteria. Differences in caries prevalence between indices were not homogeneous among schoolchildren of different socio-economic backgrounds.

The impact of including non-cavitated lesions was also evident on caries extent (*Table 2*). According to the standard WHO criteria, 1.39 teeth were affected by caries; this estimate was in contrast to a caries extent of 1.95 and 3.78 teeth according to the modified WHO criteria and ICDAS criteria, respectively. When considering caries severity according to ICDAS, cavitated lesions corresponded to 36.8% (1.39), active non-cavitated lesions (ICDAS 1 + 2) to 14.8% (0.56) and inactive non-cavitated lesions (ICDAS 1 + 2) to 48.4% (1.83) (data not cited in the tables). These estimates indicate that whereas the estimate of the modified WHO criteria was approximately 40% larger than that of the original WHO criteria, the ICDAS estimates were 2.71-fold higher. The inclusion of all non-cavitated lesions (ICDAS) increased caries extent mainly in schoolchildren with a higher socio-economic background.

Significant associations between caries prevalence and school type, socio-economic status, mother's and father's education, and crowding were consistently observed for all detection criteria (*Table 3*). Gender was the only variable that lost its significant association with caries prevalence when ICDAS was used. As shown in *Table 4*, all sociodemographic variables were significantly associated with DMFT, irrespective of the detection criteria used.

DISCUSSION

The declining occurrence of caries in several populations has raised concerns about the appropriateness of the original WHO criteria because it focusses on the detection of cavitated lesions and restored/lost teeth[1]. As widely discussed in the literature[1], caries detection at the cavity level may underestimate caries prevalence in populations. The inclusion of non-cavitated lesions improves caries detection; however, it requires the extra clinical steps of cleaning and drying of the tooth surface as well as good illumination[22] and it may affect intra- and inter-examiner reproducibility[3]. This way, a better understanding of its true benefits to caries epidemiology should be achieved before adopting more cumbersome examination strategies in oral epidemiological surveys.

Table 1 Caries prevalence according to independent variables, as assessed using the standard World Health Organization (WHO), modified WHO and International Caries Detection and Assessment System (ICDAS) criteria; absolute differences and inflation rates comparing the methods

Variable (*n*)	WHO	Modified WHO	ICDAS	Absolute differences		Inflation rates	
				WHO × modified WHO	WHO × ICDAS	WHO × modified WHO	WHO × ICDAS
Gender							
Female (758)	57.98 (45.18–70.78)	66.34 (56.16–76.52)	81.82 (73.19–90.44)	8.35** (4.53–12.18)	23.83** (13.34–34.32)	1.14*** (1.05–1.23)	1.41*** (1.15–1.66)
Male (770)	52.56 (44.93–60.18)	60.42 (53.05–67.78)	77.88 (72.64–83.12)	7.85** (4.63–11.07)	25.32*** (22.62–28.02)	1.14*** (1.07–1.22)	1.48*** (1.36–1.60)
School							
Private (261)	37.46 (22.54–52.38)	48.02 (37.88–58.15)	66.85 (56.04–77.66)	10.55** (5.54–15.56)	29.39*** (24.03–34.74)	1.28** (0.99–1.57)	1.78** (1.26– 2.30)
Public (1,267)	60.24 (50.53–69.95)	67.65 (60.11–75.20)	83.48 (80.38–86.58)	7.41** (4.46–10.36)	23.23*** (15.53–30.93)	1.12*** (1.05–1.18)	1.38*** (1.19–1.57)
Socio-economic status							
High (141)	43.13 (30.22–56.03)	52.10 (40.51–63.70)	71.11 (54.65–87.57)	8.97*** (6.75–11.20)	27.98*** (18.49–37.47)	1.20*** (1.10–1.31)	1.64*** (1.36–1.93)
Mid–high (358)	44.51 (39.70–49.33)	54.32 (49.16–59.48)	72.21 (67.81–76.60)	9. 80** (5.30–14.30)	27.69*** (25.47–29.91)	1.22*** (1.10–1.33)	1.62*** (1.52–1.72)
Mid–low (871)	60.79 (51.70–69.88)	68.31 (59.83–76.80)	84.17 (79.99–88.36)	7.52** (5.24–9.80)	23.38*** (17.57–29.19)	1.12*** (1.07–1.17)	1.38*** (1.23–1.53)
Low (158)	65.92 (57.41–74.44)	71.83 (68.58–75.09)	85.22 (81.27–89.17)	5.91 (–1.62–13.44)	19.29** (8.7–29.89)	1.08*** (0.96–1.21)	1.29*** (1.09–1.48)
Mother's education†							
University (216)	40.47 (26.96–53.98)	52.56 (46.07–59.04)	69.82 (58.81–80.82)	12.08* (4.69–19.48)	29.34*** (21.52–37.17)	1.29*** (1.01–1.57)	1.72*** (1.33–2.11)
High school (516)	51.38 (45.30–57.45)	58.30 (51.01–65.58)	77.16 (74.06–80.25)	6.92*** (5.50–8.33)	25.77*** (21.38–30.17)	1.13*** (1.11–1.15)	1.50*** (1.36–1.64)
Elementary school (789)	63.33 (53.54–73.12)	70.97 (63.28–78.65)	85.56 (83.04–88.08)	7.63** (4.90–10.36)	22.23*** (14.67–29.79)	1.12*** (1.06–1.18)	1.35*** (1.17–1.52)
Father's education†							
University (203)	36.24 (30.15–42.32)	47.16 (45.31–49.02)	66.33 (55.60–77.06)	10.92* (4.36–17.49)	30.09*** (20.49–39.69)	1.30** (1.02–1.57)	1.83*** (1.45–2.20)
High school (436)	53.04 (46.85–59.23)	60.36 (54.49–66.23)	76.76 (73.04–80.48)	7.32** (5.05–9.59)	23.72*** (20.66–26.77)	1.13*** (1.08–1.18)	1.44*** (1.34–1.55)
Elementary school (788)	62.84 (54.59–71.09)	70.31 (62.82–77.81)	85.67 (81.99–89.34)	7.47***(6.54–8.40)	22.82*** (16.75–28.89)	1.11*** (1.08–1.14)	1.36*** (1.22–1.50)
Crowding†							
Low (351)	45.52 (36.93–54.11)	55.03 (49.23–60.84)	71.32 (63.40–79.25)	9.51** (4.57–14.45)	25.80*** (22.11–29.48)	1.20*** (1.06–1.34)	1.56*** (1.40–1.72)
Medium (826)	54.63 (45.61–63.64)	62.71 (55.43–69.99)	80.41 (75.29–85.53)	8.08** (4.92–11.24)	25.78*** (21.15–30.41)	1.14*** (1.07–1.22)	1.47*** (1.31–1.63)
High (350)	68.58 (61.28–75.88)	75.07 (68.99–81.15)	88.80 (85.17–92.44)	6.48*** (4.40–8.56)	20.22** (9.31–31.12)	1.09*** (1.05–1.13)	1.29*** (1.10–1.48)
Total (1,528)	55.23 (45.26–65.19)	63.33 (55.20–71.46)	79.82 (73.89–85.75)	8.10** (5.60–10.60)	24.59*** (18.70–30.48)	1.14*** (1.07–1.21)	1.44*** (1.26–1.62)

Values are given as mean (95% confidence interval).
†Values do not sum to 1,528 because of missing data.
*$P < 0.05$; **$P < 0.01$; ***$P < 0.001$ (Wald test).

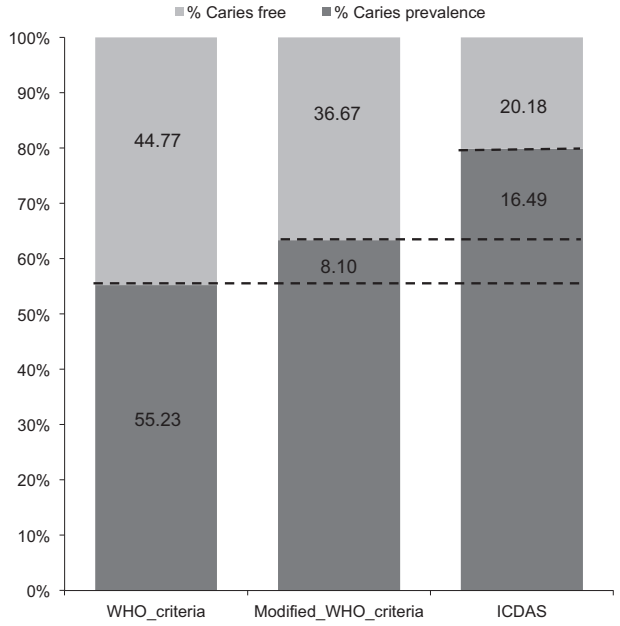

Figure 1. Caries prevalence and the proportion of caries-free individuals according to different detection criteria. ICDAS, International Caries Detection and Assessment System; WHO, World Health Organization.

Active non-cavitated caries lesions should be carefully evaluated during caries examination because intervention is needed to arrest disease progression. In this sense, the modified WHO criteria allow the identification of individuals with non-operative treatment needs. This modified WHO criteria slightly increased the estimates of caries prevalence and extent. On the other hand, when inactive lesions were also considered (ICDAS), the caries prevalence increased sharply. These findings are important in light of the current understanding of caries activity and the need for intervention. Dental surfaces are continuously undergoing the de-remineralisation process and, in this context, an inactive lesion is a self-controlled demineralisation process that does not tend to progress[20,23,24]. Therefore, the added benefit of including inactive lesions in new caries indices seems questionable, mainly when epidemiological data will be used to estimate treatment needs in populations.

A previous study compared the ability of WHO and ICDAS criteria to discriminate groups susceptible to caries[14]. Regarding caries prevalence, it was shown that the discriminatory power decreased when both non-cavitated and cavitated scores of ICDAS were included in caries assessment. Most of the children exhibited non-cavitated caries lesions, and, according to the authors, little room for showing any discrimination between the explanatory factors could be expected. Variables such as age, number of brothers and sisters and family income lost their significance when the score 1 of ICDAS was used as the cut-off[14]. The results of the present study do not corroborate this finding as the inclusion of non-cavitated lesions has not altered the associations between caries and sociodemographic variables. We could speculate that the disagreement between our results and those reported by Mendes *et al.*[14] may be attributed to issues related to sample size and statistical power.

The inclusion of non-cavitated lesions had the greatest impact on caries estimates among schoolchildren with higher socio-economic status. This is a conceivable finding as individuals living in more affluent conditions are less affected by the disease[25–27] and show a lower rate of caries progression, being more likely to present non-cavitated caries as the signs of the disease. Thus, in this subpopulation, the detection of non-cavitated lesions has a greater impact than the one observed in schoolchildren living in underprivileged conditions, who present a higher rate of caries progression and consequently a higher proportion of cavities. It is expected that the inclusion of non-cavitated lesions would promote a greater impact on caries estimates among developed countries, which have a higher proportion of individuals of high and mid-high socio-economic status and lower rates of caries prevalence and progression compared with developing countries. However, it is important to point out that the increment in caries prevalence and extent observed when inactive/brown non-cavitated lesions were included does not represent an increase in treatment needs.

As consistently described in the literature[25–27], socio-economic variables were significantly associated with caries prevalence and extent in this population. The mechanism by which these factors influence caries experience is related to the effect of a worse socio-economic background on oral health-related habits and behaviours. It has been shown that individuals living in underprivileged conditions, with lower schooling, low socio-economic strata or attending public schools, report a lower brushing frequency[28], a lower access to fluoridated products[29] or present a poorer oral hygiene[30], thus being more susceptible to caries development.

The strengths of the study include: its large population-based sample of 12-year-old schoolchildren; high participation rate (83.17%); proper diagnosis of caries activity, including tooth cleaning and surface drying before the clinical examination; and high reproducibility of the examiner. Although questionnaires are widely used in epidemiological surveys, the lack of consistency among studies and completeness may affect a study's validity. Whereas efforts were undertaken to minimise missing data, limited non-participation and item non-response did occur and this may have influenced the results of some group comparisons. It is also important to acknowledge that the validity and reliability of the questionnaire data were not assessed. The cross-sectional nature of the study obviously prevents the establishment of a causal relationship.

Table 2 Caries extent according to independent variables, as assessed using the standard World Health Organization (WHO), modified WHO and International Caries Diagnosis and Assessment System (ICDAS) criteria; absolute differences and inflation rates comparing the methods

Variable	WHO	Modified WHO	ICDAS	Absolute differences		Inflation rates	
				WHO × modified WHO	WHO × ICDAS	WHO × modified WHO	WHO × ICDAS
Gender							
Female	1.46 (1.11–1.81)	2.03 (1.60–2.45)	4.10 (3.09–5.10)	0.56*** (0.45–0.68)	2.63*** (1.71–3.56)	1.38*** (1.30–1.47)	2.80*** (2.05–3.55)
Male	1.32 (1.02–1.63)	1.88 (1.57–2.19)	3.47 (3.09–3.86)	0.55*** (0.50–0.60)	2.15*** (1.84–2.45)	1.41*** (1.31–1.52)	2.62*** (2.14–3.09)
School							
Private	0.73 (0.36–1.10)	1.18 (0.81–1.55)	2.95 (1.63–4.28)	0.45*** (0.37–0.52)	2.22** (1.23–3.21)	1.61** (1.21–2.02)	4.03*** (3.15–4.90)
Public	1.58 (1.30–1.85)	2.17 (1.89–2.44)	4.01 (3.56–4.46)	0.59*** (0.49–0.69)	2.43*** (1.90–2.96)	1.37*** (1.27–1.47)	2.54*** (2.01–3.07)
Socio-economic status							
High	0.88 (0.54–1.22)	1.19 (0.78–1.59)	2.77 (1.90–3.65)	0.30*** (0.23–0.38)	1.89** (1.12–2.66)	1.34*** (1.28–1.41)	3.14*** (2.02–4.26)
Mid–high	1.09 (0.83–1.35)	1.53 (1.34–1.72)	3.28 (2.63—3.94)	0.43*** (0.34–0.53)	2.19*** (1.58–2.79)	1.40*** (1.23–1.57)	3.00*** (2.26–3.73)
Mid–low	1.56 (1.27–1.85)	2.22 (1.89–2.56)	4.09 (3.48–4.71)	0.66*** (0.52–0.80)	2.53*** (1.95–3.11)	1.42*** (1.31–1.53)	2.62*** (2.11–3.12)
Low	1.81 (1.67–1.95)	2.41 (2.32–2.50)	4.47 (3.34–5.61)	0.60*** (0.44–0.75)	2.66** (1.50–3.82)	1.33*** (1.22–1.43)	2.46*** (1.79–3.14)
Mother's education							
University	0.80 (0.60–1.01)	1.22 (0.96–1.47)	2.74 (1.80–3.68)	0.41** (0.23–0.58)	1.93** (1.12–2.74)	1.51*** (1.25–1.77)	3.40*** (2.55–4.24)
High schoo	1.25 (1.00–1.50)	1.70 (1.34–2.07)	3.46 (2.79–4.12)	0.45** (0.27–0.63)	2.20*** (1.73–2.68)	1.36*** (1.23–1.49)	2.76*** (2.46–3.05)
Elementary school	1.70 (1.37–2.04)	2.40 (2.07–2.73)	4.38 (3.91–4.85)	0.69*** (0.61–0.77)	2.68*** (1.96–3.39)	1.40*** (1.31–1.50)	2.57*** (1.87–3.26)
Father's education							
University	0.77 (0.61–0.93)	1.15 (1.03–1.28)	2.68 (1.93–3.43)	0.38** (0.22–0.55)	1.91*** (1.29–2.53)	1.50** (1.14–1.86)	3.48*** (2.87–4.10)
High school	1.27 (1.06–1.49)	1.72 (1.48–2.01)	3.45 (2.85–4.05)	0.47*** (0.36–0.58)	2.17*** (1.69–2.66)	1.37*** (1.27–1.46)	2.70*** (2.32–3.08)
Elementary school	1.65 (1.32–1.99)	2.33 (1.95–2.71)	4.33 (3.62–5.03)	0.67*** (0.61–0.74)	2.67*** (1.91–3.43)	1.40*** (1.34–1.47)	2.61*** (1.95–3.26)
Crowding							
Low	0.99 (0.76–1.22)	1.42 (1.15–1.69)	3.16 (2.26–4.07)	0.42*** (0.32–0.53)	2.17*** (1.40–2.94)	1.43*** (1.29–1.57)	3.18*** (2.51–3.86)
Medium	1.36 (1.09–1.63)	1.91 (1.60–2.23)	3.68 (3.07–4.29)	0.55** (0.39–0.71)	2.32*** (1.78–2.85)	1.40*** (1.26–1.54)	2.70*** (2.20–3.19)
High	1.95 (1.70–2.19)	2.69 (2.48–2.90)	4.78 (3.93–5.63)	0.74*** (0.62–0.86)	2.83*** (1.83–3.83)	1.38*** (1.28–1.47)	2.45*** (1.80–3.10)
Total	1.39 (1.07–1.71)	1.95 (1.59–2.31)	3.78 (3.11–4.45)	0.56** (0.48–0.64)	2.39*** (1.77–3.00)	1.40*** (1.31–1.49)	2.71*** (2.10–3.32)

Values are given as mean (95% confidence interval).
*$P < 0.05$; **$P < 0.01$; ***$P < 0.001$ (Wald test).

Table 3 Association between caries prevalence and independent variables using the standard World Health Organization (WHO), modified WHO and International Caries Diagnosis and Assessment System (ICDAS) criteria

Variable	WHO		Modified WHO		ICDAS	
	PR (95% CI)	*P*	PR (95% CI)	*P*	PR (95% CI)	*P*
Gender						
Female	1.00		1.00		1.00	
Male	0.90 (0.84–0.97)	0.009	0.91 (0.84–0.98)	0.01	0.95 (0.88–1.01)	0.15
School						
Private	1.00		1.00		1.00	
Public	1.60 (1.17–2.20)	0.003	1.40 (1.19–1.66)	<0.001	1.24 (1.13–1.37)	<0.001
Socio-economic status						
High	1.00		1.00		1.00	
Mid–high	1.03 (0.84–1.25)	0.75	1.04 (0.85–1.26)	0.67	1.01 (0.86–1.19)	0.85
Mid–low	1.40 (1.22–1.62)	<0.001	1.31 (1.19–1.43)	<0.001	1.18 (1.02–1.36)	0.01
Low	1.52 (1.26–1.84)	<0.001	1.37 (1.19–1.59)	<0.001	1.19 (1.03–1.38)	0.01
Mother's education						
University	1.00		1.00		1.00	
High school	1.26 (1.00–1.61)	0.05	1.10 (1.00–1.22)	0.04	1.10 (1.01–1.20)	0.02
Elementary school	1.56 (1.26–1.93)	<0.001	1.35 (1.23–1.47)	<0.001	1.22 (1.10–1.36)	<0.001
Father's education						
University	1.00		1.00		1.00	
High school	1.43 (1.32–1.62)	<0.001	1.27 (1.19–1.36)	<0.001	1.15 (1.02–1.31)	0.02
Elementary school	1.76 (1.55–1.93)	<0.001	1.49 (1.37–1.61)	<0.001	1.29 (1.16–1.43)	<0.001
Crowding						
Low	1.00		1.00		1.00	
Medium	1.20 (1.09–1.31)	<0.001	1.13 (1.11–1.16)	<0.001	1.12 (1.06–1.19)	<0.001
High	1.50 (1.31–1.72)	<0.001	1.36 (1.30–1.42)	<0.001	1.24 (1.15–1.34)	<0.001

95% CI, 95% confidence interval; PR, prevalence ratio.

Table 4 Association between caries extent and independent variables using the standard World Health Organization (WHO), modified WHO and International Caries Diagnosis and Assessment System (ICDAS) criteria

Variable	WHO		Modified WHO		ICDAS	
	RR (95% CI)	*P*	RR (95% CI)	*P*	RR (95% CI)	*P*
Gender						
Female	1.00		1.00		1.00	
Male	0.90 (0.84–0.97)	0.006	0.92 (0.87–0.98)	0.01	0.84 (0.75–0.95)	0.005
School						
Private	1.00		1.00		1.00	
Public	2.15 (1.49–3.11)	<0.001	1.82 (1.49–2.23)	<0.001	1.35 (1.04–1.76)	0.02
Socio-economic status						
High	1.00		1.00		1.00	
Mid–high	1.23 (1.00–1.52)	0.04	1.28 (1.04–1.58)	0.01	1.18 (1.05–1.32)	0.004
Mid–low	1.76 (1.47–2.11)	<0.001	1.86 (1.60–2.18)	<0.001	1.47 (1.28–1.69)	<0.001
Low	2.05 (1.64–2.56)	<0.001	2.02 (1.61–2.55)	<0.001	1.61 (1.40–1.85)	<0.001
Mother's education						
University	1.00		1.00		1.00	
High school	1.55 (1.27–1.88)	<0.001	1.39 (1.09–1.79)	0.008	1.26 (1.01–1.55)	0.03
Elementary school	2.11 (1.84–2.42)	<0.001	1.96 (1.81–2.14)	<0.001	1.59 (1.29–1.96)	<0.001
Father's education						
University	1.00		1.00		1.00	
High school	1.65 (1.40–1.95)	<0.001	1.51 (1.36–1.67)	<0.001	1.28 (1.10–1.50)	0.001
Elementary school	2.15 (1.80–2.55)	<0.001	2.01 (1.73–2.34)	<0.001	1.61 (1.32–1.96)	<0.001
Crowding						
Low	1.00		1.00		1.00	
Medium	1.37 (1.27–1.47)	<0.001	1.34 (1.23–1.47)	<0.001	1.16 (1.01–1.33)	0.03
High	1.96 (1.71–2.24)	<0.001	1.89 (1.71–2.09)	<0.001	1.50 (1.25–1.81)	<0.001

95% CI, 95% confidence interval; RR, rate ratio.

The results of the present study show that the inclusion of non-cavitated lesions impacts estimates of the prevalence and extent of caries, mainly when ICDAS is used. No impact was observed on the association between caries and socio-economic variables.

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Conflict of interest

The authors declare no conflict of interest related to this study.

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