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Molar-incisor hypomineralization and dental caries: A hierarchical approach in a populational-based study

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The last couple of decades has seen an increasing interest in molar-incisor hypomineralization (MIH) studies. Hypomineralized defects can have several consequences such as hypersensitivity, increased dental plaque accumulation, and consequently higher caries risk. This cross-sectional study aimed to investigate the prevalence of MIH and its association with dental caries in schoolchildren from a city in southern Brazil. A random cluster sample of schoolchildren was selected. Clinical examinations were carried out to collect information on MIH (following the European Academy of Pediatric Dentistry criteria), dental caries (using the DMF-T index) and gingivitis. Socioeconomic, demographic and behavior variables were collected using a standardized questionnaire answered by the children's parents/caregivers. Prevalence ratios (PR) were estimated using Poisson regression analysis with robust variance through a hierarchical approach ($p<0.05$). A total of 513 schoolchildren were included in the study. MIH and caries prevalence was 19.7% and 31.6%, respectively. The mean age was 11.6 ($\pm$1.9) years. Dental caries was more prevalent in children with MIH (PR 1.39; 95% CI 1.05 – 1.85). Older children and children whose families were enrolled in conditional cash transference programs (PR 1.97 95% CI 1.47 – 2.64), and children who did not have their mother or father as the head of the family (PR 1.56 95% CI 1.06 – 2.30) presented a higher prevalence of dental caries. Our findings suggest that children with MIH are more likely to have dental caries.

Key Words: molar-incisor hypomineralization, dental caries, dental enamel hypoplasia

Introduction

Molar-incisor hypomineralization (MIH) is defined as a qualitative developmental defect of tooth enamel that affects first permanent molars, and can also affect permanent incisors (1). Several studies have evaluated the etiological factors of hypomineralization as a multifactorial defect associated with gestational factors, diseases of early childhood (2), and genetic factors (3).

A systematic review found that the global prevalence of MIH is 14.2%, ranging from 0.5% to 40.2%, depending on the country (4). Different diagnostic criteria and the heterogeneity of children's age contribute to this difference. The prevalence of MIH in Brazil, in the same way as the global prevalence, also presents important variability (5–7). Although some prior studies reported the prevalence of MIH in different regions of Brazil, there are few studies that assess MIH in the South of Brazil.

Hypomineralization is clinically characterized by demarcated opacities which vary in color from white to brown, showing clear and distinct borders with sound enamel (1). Hypomineralized enamel is more porous than normal enamel (8). The lower strength of the hypomineralized enamel can lead to post-eruptive fractures which predispose to plaque accumulation and dental caries development. Plaque accumulation is also favored by lack of proper biofilm control due to hypersensitivity of the affected teeth (9). It has been evidenced that there is a significant association between MIH and caries. Both the DMF index and caries prevalence were shown higher in children with MIH (10). However, due the low quality of the existing evidence, there is still a need of well-designed studies which robustly investigate this association (10), particularly in the South of Brazil.

Considering the importance of increasing the knowledge and volume of evidence about the impacts of MIH on oral health, the aim of this study was to report the prevalence of MIH and its

association with dental caries in schoolchildren of a city in southern Brazil. The conceptual hypothesis is that children with MIH were more likely to have dental caries.

Material and Methods

This study was reported according to the "Strengthening the Reporting of Observational Studies in Epidemiology" (STROBE) Statement (11).

Ethical Considerations

The study was conducted in accordance with the Ethical Standards of the Resolution of the National Council on Ethics in Research (no. 466/2012 and no. 510/2016) and the Helsinki Declaration (2008). The local Research Ethics Committee approved the research protocol (no. 2.632.694). Parents or guardians signed a written informed consent form and schoolchildren signed an assent form.

Study design, sample size, and participants

This cross-sectional study was conducted with schoolchildren from the 1st to the 9th year enrolled in public elementary schools in the Estância Velha city. The city is located in the South region of Brazil (Rio Grande do Sul state), and had a population of 42,574 inhabitants according to the last Brazilian census (IBGE, 2010), and a human development index of 0.808 (12). The city has 13 public municipal elementary schools with 6,467 children aged between 5 and 14 years enrolled (IBGE, 2010).

The sample size was calculated using Power and Sample Size Software, considering DMTF index and MIH averages of a previous study (1.23 ± 1.96 and 1.64 ± 3.17) (13). Using a significance level of 5% and a power of 80%, the minimum sample required was of at least 472 participants. Considering eventual losses or incomplete data, 10% was added to the sample size, resulting in 519 participants.

The sampling process used a cluster randomization; first, the list of all elementary public municipal schools was obtained, after, the classes were randomly selected (www.randomizer.org), respecting the proportion of classes selected according to the total number of students enrolled in each school.

Schoolchildren had to present all permanent incisors and first permanent molars erupted to be included in study. Participants were excluded if wearing fixed orthodontic appliances.

Data Collection

Data collection took place between April 2019 and December 2019. All exams were performed at schools and followed the international criteria standardized by the World Health Organization for oral health surveys (WHO, 2013) (14). The schoolchildren received toothbrushing by a dental undergraduate student before the clinical examinations. Subsequently, the schoolchildren were taken to a room especially prepared for data collection and placed on a chair and leaned back, resting the back of their heads on the examiner's lap. The dental examination was carried out by two previously-trained and calibrated operators (XXX and YYYY) assisted by dental undergraduate students. A flat dental mirror (Duflex, SS White, Brazil), a ball-point probe (WHO-621, Trinity, Brazil), metallic WHO CPI probe (Trinity, Brazil) and gauze swab were used under artificial lighting (desk lamp model Pelican, Startec127V, Brazil) for the dental examination.

The clinical examination included the dental caries evaluation, according to the decayed, missing, and filled teeth index (DMF-T) (14) and dichotomized considering the prevalence of untreated dental caries into "present" (corresponding to a non-zero D component in the DMFT index) or "absent" (D component of the DMFT index equal to zero) (15). In addition, the schoolchildren were evaluated regarding presence or absence of MIH, being considered present when at least one first permanent molar was affected (presented a marked opacity, post-eruptive fracture, the presence of atypical restoration, or exodontia which was attributable to MIH), with or without the involvement of the permanent incisors, according to the EAPD criteria (16). Gingivitis was assessed by inserting the periodontal probe in the gingival sulcus and running it through all its extension at a depth of 0.5mm in all the teeth. Gingivitis was considered present when there were 10% or more bleeding sites bleed after probing (17).

Demographic, socioeconomic and behavior data were collected by a self-administered questionnaire specifically developed for this study containing the following information: caregiver education, participation in conditional cash transference program *(Bolsa Familia),* family structure, the degree of kinship to the child, date of birth and age of the child, and number of dental visits in the last semester. The questionnaire was answered by the child's caregiver. Age was dichotomized by the median. The caregiver's education level was collected in years and categorized in < 8 and ≥ 8 years of formal

education. Enrollment in the conditional cash transference program was used as a proxy of family monthly income.

Calibration exercise

The researchers were trained and calibrated prior to starting the study. In the first moment, a 2-hour lecture and theoretical discussion about clinical data collection was performed. The possible differential diagnoses for MIH, such as amelogenesis, fluorosis and enamel hypoplasia were discussed. In the second moment, the researchers were tested for diagnosis using clinical images. Lastly, for calibration purposes, 10 patients from the University Clinic (Children and Youth Dental Clinic) were examined under standardized conditions, as mentioned above. The results of the examinations were compared with those of the examination performed by an Associate Professor of Pediatric Dentistry. The inter-examiner Cohen's kappa coefficient was 0.90 (A.S.A) and 0.86 (L.IL.B.) for MIH, and 0.89 (A.S.A) and 0.91 (L.IL.B.) for dental caries. The researchers were calibrated again when 50% of the sample was reached, and reproducibility was considered adequate.

Pilot Study

A total of 30 schoolchildren from the largest school who did not participate in the study were selected by convenience to participate in the pilot study. The process confirmed the adequacy of the questionnaire, examination protocol and the logistics of the study and no modifications were necessary.

Data Analysis

Data analysis was performed using the Stata 14.0 program (Stata Corp., College Station, TX, USA). The presence of dental caries was set as the main outcome of this study. Descriptive statistics were used to describe the demographic, socioeconomic and clinical characteristics of the sample. Multivariate Poisson regression analysis with robust variance were performed to evaluate the association among predictor variables in the presence of dental caries, considering a fixed effect and random intercept. An adjusted analysis following a hierarchical approach was performed (18), considering model 1 ("empty model"); model 2 including demographic and socioeconomic characteristics; model 3 was composed of model 2 plus clinical variables. Model fit was assessed according to deviance (-2loglikelihood). Variables with $p<0.20$ in the unadjusted analyses were included in the adjusted model. Age and gender variables were included by theoretical criteria (18). The results are presented as prevalence ratios (PR) and a respective 95% confidence interval (95% CI).

Results

A total of 560 schoolchildren were invited to participate in the study and 513 agreed to participate (91.6%). No participants were excluded. The average age of the students was 11.6 ($\pm$1.9) years. Table 1 shows the sample characteristics. The prevalence of MIH and dental caries was 19.7% and 31.6%, respectively. Based on clinical signs of MIH, the most frequent defects were demarcated opacities (71.3%), followed by post-eruptive fractures (14.8%) and atypical restorations (13.9%).

The unadjusted Poisson regression analysis is shown in Table 2. Dental caries was more prevalent in schoolchildren aged 12 years or more, whose families were enrolled in conditional cash transference programs, and who did not have their mother or father as head of the family (the family nucleus is not formed by the main guardian – father or mother). Finally, MIH was associated with prevalent dental caries (PR: 1.42 95% CI: 1.08 – 1.88).

Table 3 presents the multivariate regression models. After the adjustments, the variables which remained significantly associated with dental caries were age, enrollment in conditional cash transference programs, not having a father or mother as the head of the family, and MIH. In model 2, dental caries was more prevalent in schoolchildren whose families were enrolled in conditional cash transference programs, and who did not have their mother or father as head of the family. In model 3, presence of MIH was associated with dental caries (PR: 1.39 95% CI: 1.05 – 1.85).

Table 1. Sample distribution of overall dental caries scores according to socioeconomic, demographic, and clinical characteristics of the sample.

Variables	n (%)	Dental Caries mean (SD)
Demographic and socioeconomic		
Sex		
Female	281 (54.8)	0.7 (1.3)
Male	232 (45.2)	0.6 (1.1)
Age		
≤ 12 years	256 (50.3)	0.4 (0.9)
> 12 years	253 (49.7)	0.8 (1.4)
Conditional cash transference		
No	440 (89.9)	0.6 (1.2)
Yes	49 (10.1)	1.1 (1.4)
Caregiver education		
< 8 years	260 (54.39)	0.6 (1.3)
≥ 8 years	218 (45.61)	0.7 (1.1)
Head of the family		
Wife	179 (37.4)	0.6 (1.1)
Husband	246 (51.5)	0.7 (1.3)
Other	53 (11.1)	0.6 (0.9)
Behavioral variable		
Dental visit in the last 6 months		
Yes	298 (89.0)	0.7 (1.3)
No	37 (11.0)	0.4 (0.9)
Clinical variables		
MIH		
No	412 (80.3)	0.6 (1.2)
Yes	101 (19.7)	0.7 (1.0)
Gingivitis		
No	160 (31.2)	0.6 (1.1)
Yes	353 (68.8)	0.6 (1.2)

Values lower than 513 due to missing data.
SD, standard deviation.

Table 2. Unadjusted assessment of socioeconomic, demographic, clinical variables associated with presence of dental caries (Poisson regression with robust variance).

Variables	PR (95% CI)	P-value
Demographic and socioeconomic		
Sex		
Female	1	
Male	0.94 (0.73 – 1.22)	0.667
Age		
≤ 12 years	1	
> 12 years	1.44 (1.11 – 1.87)	0.006
Conditional cash transference		
No	1	
Yes	1.80 (1.33 – 2.44)	<0.001
Caregiver education		
< 8 years	1	
≥ 8 years	1.13 (0.86 – 1.47)	0.364
Head of the family		
Wife	1	
Husband	1.21 (0.90 – 1.63)	0.194
Other	1.58 (1.07 – 2.34)	0.020
Behavioral variable		
Dental visit in the last 6 months		
Yes	1	
No	0.57 (0.28 – 1.14)	0.115
Clinical variables		
MIH		
No	1	
Yes	1.42 (1.08 – 1.88)	0.011
Gingivitis		
No	1	
Yes	0.98 (0.74 – 1.29)	0.923

PR, prevalence ratio; 95% CI, 95% confidence intervals;

Table 3. Poisson regression with robust variance on the association between socioeconomic, demographic, clinical variables and presence of dental caries.

Variables	Model 1[a] PR (95% CI)	Model 2[b] PR (95% CI)	Model 3[c] PR (95% CI)
Fixed component Intercept	0.31 (0.27 – 0.35)	0.21 (0.15 – 0.28)	0.19 (0.14 – 0.27)
Demographic and socioeconomic			
Sex			
Female		1	1
Male		0.85 (0.65 – 1.11)	0.85 (0.65 – 1.11)
Age			
≤ 12 years		1	1
> 12 years		1.47 (1.12 – 1.93) *	1.47 (1.12 – 1.93) *
Conditional cash transference			
No		1	1
Yes		1.97 (1.47 – 2.64) *	1.97 (1.47 – 2.64) *
Head of the family			
Wife		1	1
Husband		1.26 (0.94 – 1.69)	1.26 (0.94 – 1.69)
Other		1.56 (1.06 – 2.30) *	1.56 (1.06 – 2.30) *
Clinical variables			
MIH			
No			1
Yes			1.39 (1.05 – 1.85) *
Random component			
Deviance (– 2 log likelihood)	697.46	631.45	628.36

[a] Model 1: empty model, unconditional model.
[b] Model 2: adjusted for demographic and socioeconomic variables.
[c] Model 3: adjusted for clinical variables.
PR, prevalence ratio; 95% CI, 95% confidence intervals; * $p < 0.05$

Discussion

The presented study investigated the association between MIH and dental caries in schoolchildren. The hypothesis that schoolchildren with MIH were more likely to have dental caries was confirmed. A hierarchical approach for modeling the variables was used in the adjusted analysis, as it was possible to avoid underestimating a distal factor on the outcome using it (19). To the best of our knowledge, this is the first study which investigated this association, as well as reported MIH prevalence using a robust sample from South Brazil. Additionally, the results confirmed the importance of socioeconomic inequalities in oral health, with an emphasis in social vulnerability, as revealed by the association between socioeconomic factors and caries.

The association between MIH and dental caries has shown in prior studies (10,13,20). The hypomineralized enamel surface is more porous when compared to sound enamel (21), contributing to greater biofilm accumulation, thus allowing demineralization (22). In addition, teeth with MIH may present hypersensitivity (23). It has been speculated that enamel porosity enables bacterial access to dentinal tubules, which can cause pulp inflammation (24). The consequence of hypersensitivity leads to important aspects such as difficulty in effective local anesthesia and the lack of brushing, with the latter being capable of increasing caries risk (23), which in turn can result in development and rapid caries progression.

The longer exposure time of the affected tooth to the oral environment, the greater the chance of post-eruptive fractures, favoring caries risk (10). This factor may have contributed to the association found in the present study, since most children evaluated were 10 years old or older. Another case-control study demonstrated that children whose molars were affected by MIH had greater caries incidence when compared to molars without MIH (13). These data corroborate our findings which indicate that MIH is associated with higher caries prevalence.

It has been shown that teeth with MIH presented a higher frequency of restorative procedures than teeth without MIH (25). The difficulty in adhesion is probably due to the affected enamel having lower mineral concentration, disorganized crystalline structure, higher carbonate content and lower

calcium-phosphate ratio (26). The mechanical properties, hardness and elasticity modulus of hypomineralized enamel also appear to be lower than those of sound enamel. Another study reported that the failure of phosphoric acid to create etching patterns in MIH teeth can break the bond compared with sound enamel (27).

The MIH prevalence found in the present study is similar to the overall prevalence found in South America (18%) reported in a recent systematic review (4). This prevalence is close to Brazilian studies which used the same criteria (18.4%; 16.2%; 19.7%) (6,28,29). On the other hand, the present study found a high prevalence in comparison with others studies (7,30), this difference is probably due to different age of participants and different ways of selecting the sample. In addition, the MIH prevalence found can be associated to a higher prevalence of respiratory disease due to humid subtropical climate of the South region of Brazil (31–33).

The present study did not find a significant association between gingivitis and dental caries, probably due to the characteristics of the sample, composed mostly of adolescents, who have a more exacerbated gingival response (34), which in turns contribute to high overall prevalence of inflammation of the gingival margin. Another similar study that used the same criteria for diagnosing gingivitis and dental caries, also found no association (34).

Recent studies suggested that distal determinants, and not only biological risk factors, influence the outcome and should also be considered in the analysis (35,36). Socioeconomic factors, such as social program receipt, were also associated with dental caries in the present study. We considered the social program receipt (family allowance) as family monthly income proxy, since this Program is a Conditional Cash Transfer Program intended to help emancipate socioeconomically vulnerable families (37), considering that these families present low monthly income. Some authors found a difference in the caries prevalence in relation to socioeconomic factors, where adolescents from a lower socioeconomic background and poor school context had higher means of dental caries over time (38), corroborating the present findings. Thus, strategies aimed at minimizing economic disparities are indispensable for improving oral health.

Children in which the family nucleus or the head of the family is not formed by the main guardian (father or mother) had a higher prevalence of dental caries in the present study. Although there is no solid evidence to thoroughly investigate the relationship between dental caries and the head of the family, the fact that children cared for by another person other than a mother may indirectly reflect a family breakdown, or less social support. This factor can contribute to worse oral health outcomes (39), in addition to a lower frequency of toothbrushing (40), which explains the significant association in the present study.

This study has some limitations, including sampling only children from public schools, which limits external validity. The cross-sectional design also prevents establishing a causal relationship. The fact that we examined children aged over 8 years (the age recommended by the EAPD for diagnosis of MIH) is both a limitation because of measurement bias, and a strength, because time-lags for caries development if examining only younger children were avoided; furthermore, only children who had erupted molars and incisors were included. Additional strengths include a robust adjustment for well-known demographic, socioeconomic, behavior and biological confounders.

In conclusion, our findings suggest that MIH was independently associated with dental caries in schoolchildren from a south Brazilian city. Surveillance of MIH in the school environment might represent an opportunity to prevent caries and promote health as part of school health promotion programs.

Resumo

Nas últimas duas décadas, observou-se um interesse crescente nos estudos de hipomineralização molar-incisivo (HMI). Os defeitos hipomineralizados podem ter várias consequências, como hipersensibilidade, aumento do acúmulo de placa dentária e, consequentemente, maior risco de cárie. Este estudo transversal teve como objetivo investigar a prevalência de HMI e sua associação com cárie dentária em escolares de um município do sul do Brasil. Uma amostra aleatória de alunos por conglomerado foi selecionada. Os exames clínicos foram realizados para coletar informações sobre HMI (seguindo os critérios da European Academy of Pediatric Dentistry), cárie dentária (usando o índice DMF-T) e gengivite. Variáveis socioeconômicas, demográficas e comportamentais foram coletadas por meio de um questionário padronizado respondido pelos pais / responsáveis pelas crianças. Razões de prevalência (RP) foram estimadas por meio de análise de regressão de Poisson com variância robusta por meio de

abordagem hierárquica (p <0,05). Um total de 513 escolares foram incluídos no estudo. A prevalência de MIH e cárie foi de 19,7% e 31,6%, respectivamente. A média de idade foi de 11,6 (± 1,9) anos. A cárie dentária foi mais prevalente em crianças com HMI (RP 1,39; IC 95% 1,05 - 1,85). Crianças mais velhas e crianças cujas famílias estavam matriculadas em programas de transferência condicional de renda (RP 1,97 IC95% 1,47 - 2,64), e crianças que não tinham a mãe ou o pai como chefe da família (RP 1,56 IC95% 1,06 - 2,30) apresentaram maior prevalência de cárie dentária. Nossos resultados sugerem que crianças com HMI são mais propensas a ter cárie dentária.

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