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Demarcated opacity in primary teeth increases the prevalence of molar incisor hypomineralization

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Abstract: This cross-sectional study aimed to assess the prevalence of molar incisor hypomineralization (MIH) and its relationship with the number of primary teeth with developmental defects of enamel (DDE). A representative population-based sample of 731 schoolchildren was randomly selected from the public school system in Curitiba, Brazil. Schoolchildren aged 8 years with fully erupted permanent first molars and incisors were eligible for the study. MIH and DDE were classified by four calibrated examiners (kappa > 0.75) according to EAPD criteria and to the FDI-modified DDE index. Clinical data were collected in a school environment. Socioeconomic information was collected through a self-administered semistructured questionnaire applied to the children's caregivers. Statistical analyses were carried out using Poisson multiple regression with robust variance (α = 0.05). MIH prevalence was 12.1% (95%CI: 10–15), and opacities were the most prevalent defect. Socioeconomic factors were not associated with MIH. Children with demarcated opacity in primary teeth presented a higher prevalence of MIH than those without DDE in primary teeth. In the multiple analysis, the increase of one primary tooth affected by demarcated opacity increased the prevalence of MIH by 33% (PR = 1.33, 95%CI: 1.15–1.53, p < 0.001). Asian children had a higher prevalence of MIH (PR = 2.91, 95%CI: 1.08–8.09 p = 0.035) than did Caucasian children. Conclusion: Based on these findings, the prevalence of MIH in Curitiba was 12.1%. Demarcated opacity in primary teeth could be considered a predictor of MIH.

Keywords: Dental Enamel Hypoplasia; Tooth, Decicuous; Epidemiologic Studies.

Introduction

Molar incisor hypomineralization (MIH) was described in Sweden in 1970, and the term was standardized by the European Academy of Pediatric Dentistry (EAPD) in 2003. It consists of a specific qualitative developmental defect of enamel (DDE), clinically characterized by demarcated opacities that affect first permanent molars and occasionally involves permanent incisors.[1] The changes in the enamel structure are asymmetric between the dental arches and may range from enamel opacities to large structural losses requiring dental intervention.[2] MIH

prevalence presented in the literature varies across different countries from 6.3% in India[8] to 40.2% in Brazil.[3] In a review study, MIH has shown a high prevalence globally.[4]

Similar clinical characteristics of MIH are also observed in primary teeth.[5, 6] Demarcated opacity in second primary molars has been defined as hypomineralization of second primary molars (HSPM).[7] It presents from one to four second primary molars. Studies report HSPM prevalence between 0 and 21.8% across different countries.[7,8] In primary teeth, the prevalence of all types of DDE ranges from 4.6% in Nigeria[9] to 48.0% in Brazil.[10] These DDE have been observed in canines and in primary molars, and a significant association with MIH has been shown.[5,6,8] This fact can be associated with the overlap of dental development periods and mineralization of canines, first and second primary molars, and first permanent molars; however, it is important to highlight that the enamel maturation process is relatively larger in permanent molars.[5,11,12]

A recent systematic review found that the presence of HSPM is predictive of MIH, and that the association between defects appears more important in the presence of mild HSPM, with demarcated opacities in second primary molars as a predictor of an increased risk for MIH.[13]

The study of MIH and its relationship with DDE in primary teeth is fundamental since it is possible to identify a high-risk group for MIH, allowing for the earlier diagnosis of MIH. Enamel defects are highly frequent in clinical practice, presenting higher susceptibility to dental caries,[14] and more complex dental care. They may be associated with large fractures of the tooth structure, sensitivity, difficulty in the bonding of restorative materials, and need for retreatment.[2,15,16,17] To the best of our knowledge, MIH prevalence in southern Brazilian cities and towns has not been investigated yet. The literature has evaluated the association between HSPM and MIH. The purpose of the present study is to analyze not only the prevalence of both enamel defects, but also to test whether the prevalence of MIH could be influenced by the number of primary teeth (molars and canines) affected by DDE, mainly by hypoplasia and demarcated opacity.

Methodology

This cross-sectional study was approved by the Research Ethics Committee of Health Sciences of the Universidade Federal do Paraná (1.613.829 / 2016). After approval, schoolchildren and their parents or legal guardians signed an informed consent form for their participation in the study. This study was reported according to the STROBE statement for observational studies (https://www.strobe-statement.org).

Sampling

The study participants were selected from public schools in Curitiba, state capital of Paraná, Brazil, which has a population of 1,908,359 inhabitants. In 2016, Curitiba had 143,701 children aged 8 years enrolled in the public school system, according to 2010 data from the Brazilian Institute of Geography and Statistics,[18] and a Human Development Index (HDI) of 0.823, ranking in 10th place among Brazilian cities and towns according to the United Nations Development Program (UNDP).

In order to obtain a representative sample, sample size was calculated with a finite population, the proportion of DDE in this population was set at 50%, an accuracy of 5% was used, a design effect factor of 1.8 was established for cluster sampling, and a boundary of 1.96 (20%) for the rejection area was added to compensate for occasional losses, resulting in a final sample of 690 to 865 children.

The sample was selected based on the proportion of schoolchildren in nine health districts of Curitiba. The sampling process used two-stage clustering. First, two schools were randomly selected from each health district, and schoolchildren from those schools were subsequently chosen at random. The randomizations were obtained from www.randomizer.org.

Schoolchildren whose parents or legal guardians had signed the informed consent form were eligible for the study. Schoolchildren wearing orthodontic braces were excluded from the study because visualization would be impaired. Schoolchildren with anodontia, oligodontia, and amelogenesis imperfecta were also excluded.

Pilot study

A pilot study was conducted with 80 school children, in the same age range as those of the main study, from the municipal public school system. The clinical examination was performed under the same conditions and criteria established in the main study. Questionnaires were also applied to parents or legal guardians in order to evaluate the understanding and possible changes in the proposed methods. Participants from the pilot study were not included in the sample.

Data collection

Four examiners underwent training and calibration protocols for collection of clinical data on DDE and MIH, using the modified DDE index[19] and the MIH criteria established by the European Academy of Pediatric Dentistry (EAPD).[20] Demarcated opacity, diffuse opacity, and hypoplasia were assessed in the case of DDE, and demarcated opacity (white, yellow, or brown), post-eruptive fracture (involving enamel or enamel and dentin), atypical restoration (satisfactory or unsatisfactory), and exodontia were used for assessment of MIH. Thirty intraoral photographs of DDE in primary teeth were selected, and the clinical characteristics and situations associated with the differential diagnosis were discussed. After that, 60 different photographs, involving all the different clinical manifestations of DDE, were selected and analyzed independently by the examiners.[19] One week later, the examiners (duplicate examination) independently analyzed the same photographs in a different order. For estimation of the interrater reliability, the obtained scores were compared with the reference standard from an expert examiner. The objective of calibration was to achieve good to excellent interrater and intrarater reliability (kappa ≥ 0.75). Intrarater and interrater kappa values were ≥ 0.75.

The clinical data were collected in a school environment, under artificial lighting conditions, using a mouth mirror, a blunt-tipped WHO probe, and sterile gauze. Only demarcated opacities greater than 1.0 mm in diameter were considered,[20] and the differential diagnosis between them and white spot lesions was based on the criteria proposed by Seow.[21] The data were collected between November 2016 and September 2017.

A semistructured questionnaire was applied to children's parents or legal guardians to gather socioeconomic information, including sex, age, self-reported ethnicity, marital status, family structure, number of household members, monthly family income, and parental level of education.

Statistical analysis

Independent variables were categorized and analyzed descriptively. Family structure was dichotomized into nuclear, when there was a stable relationship between parents or legal guardians, and non-nuclear, when parents or legal guardians were single or widowed. Family income was dichotomized based on the median of the sample into ≤ 2 Brazilian monthly minimum wages (BMMW) and > 2 BMMW. The level of education of parents or legal guardians was dichotomized into ≤ 8 years and > 8 years of schooling. Ethnicity was self-reported by parents or legal guardians.

For the prevalence rates and association analysis, DDE and MIH variables were dichotomized into present and absent. The presence of MIH was computed when at least one first permanent molar was affected by hypomineralization. The presence of DDE in primary teeth was computed when at least one primary tooth was affected by hypoplasia or demarcated opacity. A Poisson multiple regression model with robust variance was built to evaluate the relationship between MIH and DDE in primary teeth. Independent variables with p-value < 0.20 in the univariate regression analysis were included in the model according to the stepwise forward selection. For the multiple model, DDE in primary teeth was computed as a quantitative variable, considering the number of primary teeth affected by demarcated opacities. Statistical Package for Social Sciences for Windows, version 19.0 (SPSS Inc., Chicago, USA), and STATA (version 14.0; Stata Corp. LLC, College Station, TX, USA) were used for the statistical analyses.

Results

A total of 784 pairs of children and parents or legal guardians agreed to participate in the study. Of these, 733 children were examined, 51 children were not present on the day when the data were collected, and two children were excluded from the study for wearing orthodontic braces. Therefore the final sample consisted of 731 children. The socioeconomic and demographic data are presented in Table 1.

MIH prevalence was 12.1% (n = 88, 95%CI: 10–15). There was a higher prevalence of MIH in tooth 46 (8.1%), followed by tooth 36 (7.5%), tooth 16 (6.5%), and tooth 26 (5.7%). In incisors, MIH prevalence was higher in tooth 11 (4%), followed by tooth 21 (2.3%). Regarding the severity of MIH, demarcated opacities were the most prevalent defects (8.6% for yellow opacity, 7.3% for white opacity, and 1.9% for brown opacity), followed by loss of structure (1.2% in enamel and 1.2% in enamel and dentin) and atypical restorations (satisfactory in 0.8% and unsatisfactory in 0.7%).

DDE prevalence in primary teeth (demarcated opacity and/or hypoplasia) was 13.7% (n = 100). Among the evaluated types of DDE, demarcated opacity was the most prevalent, affecting 12.5% of the total sample, whereas the prevalence of dental hypoplasia was 1.8% (Table 2). The higher prevalence of demarcated hypomineralization was observed in second primary molars (4.4% for tooth 85, 3.8% for tooth

Table 1. Socioeconomic characteristics of 8-year-old schoolchildren in the city of Curitiba, Brazil, 2017 (n = 731).

Characteristics	n (%)
Sex	
Male	374 (51.16)
Female	357 (48.84)
Ethnicity	
Caucasian	617 (84.40)
Afro-descendant	89 (12.18)
Asian	11 (1.50)
Indigenous	14 (1.92)
Family BMW	
> 2BMW R$ per month	258 (35.3)
< 2BMW R$ per month	473(64.7)
Mean: 2.000.26 SD = 1660.94	
Schooling	
> 8 years	518 (71.65)
≤ 8 years	205 (28.35)
Number of household members	
< 4	487 (66.62)
≥ 5	244 (33.38)
Family structure	
Nuclear family	501 (69.58)
Non-nuclear family	219 (30.42)
Health districts	
Matriz	24 (3.28)
Cajuru	95 (13)
Bairro Novo	89 (12.18)
Boqueirão	85 (11.63)
Pinheirinho	130 (17.78)
Boa vista	95 (13)
Portão	54 (7.39)
CIC	104 (14.23)
Santa Felicidade	55 (7.52)

Note: BMW: Brazilian minimum wage in Reais per month; Nuclear families: when there was a stable relationship between parents or legal guardians, and non-nuclear, when parents or legal guardians were single or widowed.

Table 2. Prevalence of molar incisor hypomineralization (MIH) and developmental defects of enamel (DDE) in primary teeth according to severity (Curitiba, Brazil, 2017).

MIH		
Severity	PRESENT	ABSENT
	n (%)	n (%)
White opacity	53 (7.3)	678 (92.7)
Yellow opacity	63 (8.6)	668 (91.4)
Brown opacity	14 (1.9)	717 (98.1)
Loss of structure (enamel)	12 (1.2)	719 (98.4)
Loss of structure (enamel and dentin)	9 (1.2)	722 (98.8)
Atypical restorations – satisfactory	6 (0.8)	725 (99.2)
Atypical restorations – unsatisfactory	5 (0.7)	726 (99.3)
Atypical extraction	0 (0.0)	0 (0.0)
MIH with incisor involvement	48 (6.6)	683 (93.4)
DDE in primary teeth		
DDE	PRESENT	ABSENT
	n (%)	n (%)
Demarcated opacity	90 (12.5)	631 (87.5)
Hypoplasia	13 (1.8)	718 (98.2)

75, 4.2% for tooth 55, and 2.2% for tooth 65), followed by canines, which were the most severely affected teeth in the primary dentition, with the prevalence of demarcated opacity ranging from 1.0% to 1.8%.

Table 3 shows the crude PR (cPR) for MIH considering the characteristics of the sample. There is a significant association between the presence of DDE in primary teeth and MIH. The presence of demarcated opacity significantly increased the prevalence of MIH (cPR = 2.12 95%CI: 1.35–3.28; p = 0.001), and the higher the number of primary teeth with demarcated opacity, the higher the prevalence of MIH (cPR = 1.32 95%CI: 1.15–1.52, p < 0.001). MIH was not associated with socioeconomic factors. In the bivariate analysis, indigenous and Asian ethnicities tend to have a higher prevalence of MIH.

Table 3. Crude Prevalence ratio (cPR) of MIH according to DDE in primary teeth and socioeconomic characteristics of the sample (Curitiba, Brazil, 2017).

Characteristics	MIH		cPR (95%CI)	p-value
	YES (%)	NO (%)		
Sex				
Female	39 (10.9)	318 (89.1)	reference	0.366
Male	49 (13.1)	325 (86.9)	1.19 (0.80–1.78)	
Ethnicity				
Caucasian	69 (11.2)	548 (88.8)	reference	0.521
Afro-descendant	12 (13.5)	77 (86.5)	1.20 (0.68– 2.13)	
Asian	3 (27.3)	8 (72.7)	2.34 (0.90– 6.56)	0.078
Indigenous	4 (28.6)	10 (71.4)	2.55 (1.08– 6.02)	0.032
Family BMW				
> 2 BMW	25 (9.69)	233 (90.31)	reference	0.155
≤ 2BMW	63 (13.32)	410 (86.68)	1.37 (0.88–2.13)	
Schooling				
> 8 years	66 (12,7)	452 (87.3)	reference	0.264
≤ 8 years	20 (9.8)	185 (90,2)	0.76 (0.47–1.22)	
Number of household members				
< 4	56 (11.5)	461 (88.5)	reference	0.526
≥ 5	32 (13,1)	212 (86,9)	1.14 (0.79– 1.71)	
Family structure				
Nuclear family	58 (11,58)	443 (58,0)	reference	0.645
Non-nuclear family	28 (12,8)	191 (87,2)	1.10 (0.72–1.68)	
DDE in primary teeth				
No	66 (10.5)	565 (89.5)	Reference	<0.001
Yes	22 (22.0)	78 (78.0)	2.10 (1.36–3.24)	
Demarcated opacity				
No	66 (10.5)	565 (89.5)	Reference	0.001
Yes	20 (22.2)	70 (77.8)	2.12 (1.35– 3.28)	
Hypoplasia				
No	86 (12.0)	632 (88.0)	reference	0.708
Yes	2 (15.4)	11 (84.6)	1.28 (0.35– 4.67)	
Number of teeth with demarcated opacity (Mean SD, min-max)	Mean (SD) 0.22 (0.73)	min-max 0–7	1.32 (1.15–1.52)	<0.001

Note: Crude Prevalence ratio (cPR) calculated by Poisson regression analysis. Level of significance: 0.05.

Table 4.- Adjusted prevalence ratio ($_{a}$PR) of MIH according to number of DDE in primary teeth and socioeconomic characteristics of the sample. (Curitiba, Brazil, 2017).

Characteristics	MIH	
	aPR (95%CI)	p-value
Ethnicity		
Caucasian	reference	
Afro-descendant	1.19 (0.66–2.14)	0.549
Asian	2.91(1.08–8.09)	0.035
Indigenous	2.09 (0.73–5.96)	0.168
Family BMW		
> 2 BMW	reference	0.147
≤ 2BMW	1.38 (0.89–2.16)	
Number of teeth with demarcated opacity	1.33 (1.15–1.53)	<0.001

Note: aPR= Adjusted prevalence ratio. Level of significance: 0.05; BMW: Brazilian minimum wage in Reais per month

Table 4 shows the adjusted prevalence rate of MIH in relation to DDE, considering ethnicity and *per capita* income. The increase of one primary tooth affected by demarcated opacity increased the prevalence of MIH by 33% (aPR = 1.33, 95%CI: 1.15–1.53, p < 0.001). Asian children had a higher prevalence of MIH (aPR = 2.91, 95%CI: 1.08–8.09 p = 0.035) than did Caucasian children.

Discussion

The MIH prevalence found in the present study was 12.1% (95%CI 10–15), which is in line with the findings obtained for other South American populations.[3,14,22] Similar rates were also observed in Bosnia and Herzegovina (12.3%),[23] Singapore (12.5%),[24] and Iran (12.7%).[25] According to these prevalence data, MIH could be considered a public health problem, once teeth with MIH are the ones with greater need of preventive, restorative, endodontic, extraction, or orthodontic treatments.[15] Moreover, children with MIH make more visits to the dentist.[26] In our sample, 3.1% of the children needed restorative treatment for permanent teeth due to MIH. Previous studies[27,28] have reported that yellow and brown opacities in first permanent molars were at a higher risk for fracture or for carious lesions. Neves et al.[28] observed that 14% of white opacities and 27.5% of yellow opacities maximized the likelihood of enamel breakdown, exposing the dentin. Thus, opacities should also be preventively treated, either with fluoride application or sealants.[33]

MIH is considered a systemic pathology due to the involvement of permanent first molars and incisors within a similar chronological period.[1] The asymmetrical pattern of MIH in molars suggests that ameloblasts are affected by a systemic disorder at a very specific stage of their development.[12] This could result in enamel defects not only in permanent first molars and incisors, but also in primary teeth, due to the similar chronological period. The literature has shown an association between DDE in primary teeth and MIH, especially in the case of HSPM. In a recent systematic review that included a meta-analysis, HSPM was deemed to be a predictor of MIH with an overall odds ratio of 4.66 (95%CI: 2.11–10.26; p < 0.001).[13]

Unlike the previous studies reported in a systematic review,[14] the present study found not only this association in second primary molars, but also a significant increase in the prevalence of MIH according to the number of primary teeth with demarcated opacities. The increase of one primary tooth with demarcated opacity increased the prevalence of MIH by 33%, regardless of other variables. Although MIH was defined as a specific enamel defect in permanent first molars and incisors, these findings suggest that similar demarcated opacities could have affected other teeth than second primary teeth, depending on the severity of the exposure.

The association of MIH with demarcated opacity in primary teeth has been previously described. Da Silva et al.[6] observed that Brazilian children with opacity in second primary molars or in primary canines were six times more likely to develop MIH. The association between demarcated opacity in primary teeth and MIH, and their similar clinical characteristics, can be explained by the development of canines and primary molars concomitantly with the development of first permanent molars. Thus, it is suggested that systemic or environmental events combined with genetic ones in specific moments of dental development can alter the

eruption of second primary molars and of first permanent molars,[5,29] depending on the duration and/or severity of exposure.

Considering the distribution of the affected teeth, lower teeth were the most severely affected by MIH. These findings differ from those found for 12-year-old Chinese children, in whom maxillary first permanent molars were the most frequently affected by MIH.[30] This is in line with the findings of Temilola et al.,[9] who observed MIH in 60% of maxillary teeth and 40% in mandibular teeth. By evaluating enamel defects in second primary molars, it was observed that maxillary teeth were also the most frequently affected.[29] These differences can be explained by the chronology of dental development and by the length of exposure to risk factors. It is known that the eruption of mandibular teeth could occur earlier than that of maxillary ones,[11] so younger children can be exposed to proportionally larger systemic insults than can older children.

The prevalence of MIH in incisors was 6.6%, and maxillary incisors were more frequently affected than mandibular ones, as observed in a Saudi Arabian population of children aged 8–12 years,[31] as well as in Chinese children with a mean age of 12 years.[25] The definition of MIH establishes that incisors may be involved or affected and, when affected, they usually present mild involvement when compared to molars, with opacities that may need esthetic treatments,[22] which are less invasive than the restorative treatments required by molars subjected to masticatory forces. This represents a greater risk of fracture of the hypomineralized enamel, leading to structural losses. It is known that more molars are affected by MIH and that the chance of hypomineralization in incisors is higher.[3,32] It suggested that, in 6.6% of the sample, there could be a larger number of teeth with MIH.

Clinical characteristics in teeth affected by hypomineralization may vary in severity from opacities to structural losses or extensive atypical restorations.[33] In the present study, demarcated opacities were the most prevalent manifestations of MIH, followed by loss of post-eruptive enamel and atypical restorations. Other studies have also shown demarcated opacities as the most prevalent manifestation of MIH.[22,31,34] This finding can be explained by the age of the children examined (8 years), which is the ideal age for the diagnosis of MIH.[35] At this age, there might be a relatively short time for permanent teeth to be exposed to masticatory forces and, consequently, to the risk of post-eruptive fractures. The cross-sectional design of the present study was a limitation because it only allows evaluating the real situation of children in a specific time period. Hence, prospective longitudinal studies are needed, since the severity of MIH is proportional to the increase in children's age.[22] However, for this specific association between primary and permanent teeth, observed clinically, this limitation could be reduced by the age of the sample. Once the age of 8 years is considered the ideal age for the diagnosis of MIH in permanent teeth, as described previously,[21] past events during tooth development (prenatal and postnatal periods) could be observed by DDE in primary teeth (in canines and molars) at this age.

In the present study, the prevalence of DDE in primary teeth (demarcated opacity and/or hypoplasia) was 13.7%, with demarcated opacity as the most prevalent defect and second primary molars as the most frequently affected teeth. Studies have shown that, in primary teeth, there are specific groups (*e.g.*, second primary molars) more commonly affected by enamel defects, more specifically by demarcated opacities.[36,37] The prevalence of HSPM ranges from 0 to 21.8% among studies conducted in different countries.[7]

There is no study evaluating the relationship between MIH and ethnic groups. In the present study, Asian children presented a higher prevalence of MIH than did Caucasian children. To the best of our knowledge, this is the first study to show the relationship between DDE and different ethnic groups. Although the sample of this study is representative of the population of schoolchildren, these results should be interpreted with caution, because the number of Asian children (1.50% of the study population) is small in our population. This suggests that future studies could investigate whether there is a predisposition to DDE among different ethnic groups that could be related to genetic alterations.

Conclusion

MIH prevalence in the present study was 12.1%. Each primary tooth with demarcated opacity increased the prevalence of MIH by 33%, suggesting that demarcated opacity in primary teeth can be a strong predictor of MIH in the future permanent dentition. Also, Asian children had a higher prevalence of MIH than did Caucasian children.

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