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Prevalence of Molar-Incisor Hypomineralization In Milwaukee, Wisconsin, USA: A Pilot Study

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Prevalence of molar-incisor hypomineralization in Milwaukee, Wisconsin, USA: a pilot study

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Purpose: This pilot study investigated the prevalence of Molar-Incisor Hypomineralization (MIH) in third-grade school children in Milwaukee Wisconsin, USA.

Methods: A convenience sample of third-grade school children in the Milwaukee Public School System (MPS) participated in the study. Calibrated examiners trained on the European Academy of Paediatric Dentistry (EAPD) MIH recommendations examined the children between December 1, 2014 and June 30, 2015. Children were examined at their schools using a flashlight and mirror after receiving consent from parents/caregivers and assent from each child. Findings were recorded onto a standardized form by one of five trained examiners. Summary statistics were calculated, and bivariate analysis were done to identify factors associated with MIH.

Results: A total of 375 children (average age =8.66 years, range 7–12) were examined, 60% females and 41% Hispanics. Overall, 36 (9.6%) of the children demonstrated findings consistent with the diagnosis of MIH. Among the teeth with MIH defects, severe defects were higher in lower molars. There were no statistically significant differences between those with and without MIH by sex, race/ethnicity, and socioeconomic status in this study.

Conclusion: The study revealed that 9.6% of the children examined were affected by MIH. Future studies should focus on statewide and/or nationwide surveys in the United States to ascertain the extent and severity of the condition.

Keywords: molar incisor hypomineralization, MIH, children, prevalence, United States

Introduction

Molar-incisor hypomineralization (MIH) is a condition that has been previously reported in the literature under numerous names including idiopathic enamel hypomineralization, idiopathic enamel opacities, non-fluoride enamel opacities, and colloquially in a study conducted on Netherlands' children as "cheese molars".[1] Common clinical dental findings in patients included under all these terms are opaque areas that reflect a qualitative reduction in the density of the enamel on the permanent first molars (PFMs) and permanent maxillary and mandibular incisors. These areas on the PFMs can be especially prone to rapid chipping and fracture (identified as post-eruptive breakdown (PEB)), with rough enamel margins that collect plaque and may become grossly carious, including pulpal involvement, in a short period of time. In 2001, Weerheijm et al. recommended the formal name of molar incisor hypomineralization which encompassed the characteristics of all prior names for the disorder.[2] The characteristics of MIH include the presence of sharply demarcated areas of discolored enamel (white, yellow, to brown) typically on permanent first molars, sometimes on permanent

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incisors, and occasionally on other teeth.[2,3] The presence of demarcated enamel must be present on at least one molar for the condition to be termed MIH because demarcations on incisors could potentially be due to other etiologies.[2] It is also important to recognize developmental defects of enamel that are not included in the diagnostic criteria of MIH such as hypoplastic enamel (a quantitative reduction in the thickness of the enamel), fluorosis (horizontal thin white lines, opacities, discolorations, and pitting)[3] and other diffuse opacities, amelogenesis imperfecta (which affects all of the teeth),[4] white-spot lesions caused by the caries process, and those caused by physical trauma to the developing enamel organ.[5]

The exact causes of MIH are still unknown. Silva et al[6] completed a systematic review of the etiology of MIH and reported that a limited number of studies reported significant associations between MIH and several pre- and perinatal events such as maternal illness, medication used in pregnancy, prematurity, and birth complications. They also found that early childhood illnesses, specifically fevers, asthma, and pneumonia were associated with the finding of MIH when the PFMs erupted.

Management of hypomineralized teeth pose a challenge in a clinical situation. This is due to the porosity of the hypomineralized enamel, tendencies for the clinical crown to crumble under normal occlusal function,[7,8] and chronic inflammation of pulpal tissues which make these teeth difficult to adequately anesthetize.[9,10] The poorer mineral quality of these teeth can make it difficult to retain a restoration other than full coverage.[8] Chronic pulpal inflammation, the resulting lack of profound analgesia from local anesthetics, and a higher incidence of restoration replacement place these patients at a higher risk of developing dental fear.[9] Due to the difficulty in treating PFMs affected by MIH, prevalence studies are an important parameter to consider. Understanding the prevalence of a disease or condition in a population helps those charged with caring for these patients understand the burden of the condition in that population while also assisting insurers and others in planning for adequate funding available to treat the condition and its related co-morbidities.[11]

Prevalence of MIH varies depending on the country of origin and cohort of subjects evaluated. Reports that have documented MIH in multiple countries throughout the world, except from the United States and Canada, reveal that prevalence rates vary from a low of 2.4%[12] to a high of 40.2%.[13] In an attempt to contribute US information to the prevalence reports, this pilot study was initiated to determine the prevalence of MIH in a group of third grade school children living in Milwaukee, Wisconsin, USA.

Methods

This is a cross-sectional study based on a convenience sample. Human subjects research approval was obtained from both Marquette University's Institutional Review Board (MUIRB HR-2865) and the MPS Department of Research and Development (R&D) and this study was conducted in accordance with the Declaration of Helsinki. Data collection for MIH was in accordance with the European Academy of Paediatric Dentistry's (EAPD) recommendations for documenting MIH.[2] Children attending the third grade of the Milwaukee Public School (MPS) system were recruited to participate in the study. This grade group was selected because the EAPD recommends this as the ideal age and most eight year-old children attend the third grade in US schools.[2] At participating schools, children were sent home with recruitment packets. The subject recruitment packets included a recruitment letter, informed consent letter, and a demographic questionnaire (age, sex, race, income level). The parents/guardians of the children were asked to review the consent. If they desired to have their children screened, they were asked to sign the consent form, complete the demographic questionnaire, and return both to the school nurse via the student. Schools that reported consents had been returned were then scheduled for a visit by the examination team.

Prior to the screening examination, all participating children provided assent to the exam and signed the assent forms. The inclusion criteria included 1) child in the third grade at school; 2) consent of the parent and assent of the child for examination; 3) children with four fully erupted PFMs. The exclusion criteria consisted of 1) refusal of permission/assent; 2) children with significant medical conditions; 3) widespread anomalies of tooth development such as amelogenesis imperfect, enamel hypoplasia, or extensive caries which would prevent adequate clinical exam; and 4) orthodontic bands, crowns, or space maintainers on permanent first molars (PFMs) which would preclude adequate examination of the teeth. Calibrated examiners examined the teeth of the consented and assented children at the children's school using a mouth mirror, artificial light, universal precautions, and an assistant to record findings during the examination. Gauze was available to remove plaque/food debris to adequately visualize the teeth. The examiners used the

definitions provided by Weerheijm et al[2] and reported on the presence of any demarcated opacities (demarcated defect involving an alteration in the translucency of the enamel, variable in degree, enamel is of normal thickness with a smooth surface and can be white, yellow, or brown); post-eruptive enamel breakdown (a defect that indicates deficiency of the surface after eruption of the tooth, loss of the initially formed surface enamel after tooth eruption, and the loss of enamel often associated with a pre-existing demarcated opacity); atypical restorations (size and shape of restorations that are not conforming to the contemporary caries preparation with many cases having the restorations extending to the buccal or palatal/lingual smooth surface, opacity frequently found at the margin of the restoration, buccal restorations on incisors that are not associated with trauma, including SSC on molars when other signs of MIH are present); extracted molar(s) if other signs of MIH were present, and unerupted molars and/or incisors. The findings were recorded for each surface (occlusal, buccal, lingual, mesial, and distal) for all four PFMs and all eight permanent incisors. Severity of MIH was recorded using the EAPD scale of mild (demarcated opacities without enamel breakdown, occasional sensitivity to external stimuli) and severe (demarcated enamel with breakdown, caries, and persistent/spontaneous hypersensitivity) (Figure 1). Children who had any MIH-like finding on anterior teeth only were not scored as having MIH. A report of the findings was sent home with the children, and all children who had dental disease, regardless of the presence or absence of MIH, were given referrals to local dental clinics for care if they did not already report a dental home.

Examiner calibration

All examiners (MD, MA, CG, CO, and BH) underwent calibration training which consisted of one hour of didactic instruction on the EAPD definitions of sharply-demarcated lesions, PEB, and atypical restorations, including projected photographs of examples of the definitions. After the didactic session, each examiner took an examination from a Power Point presentation (Microsoft Corp., Redmond, WA, USA) consisting of 10 photographs including MIH lesions (mild and severe) as well as non-MIH lesions (enamel hypoplasia, Turner's hypoplasia, fluorosis) and the examiners recorded their diagnoses. Inter-examiner and intra-examiner reliabilities were calculated using Cohen's Kappa statistics comparing the examiners'

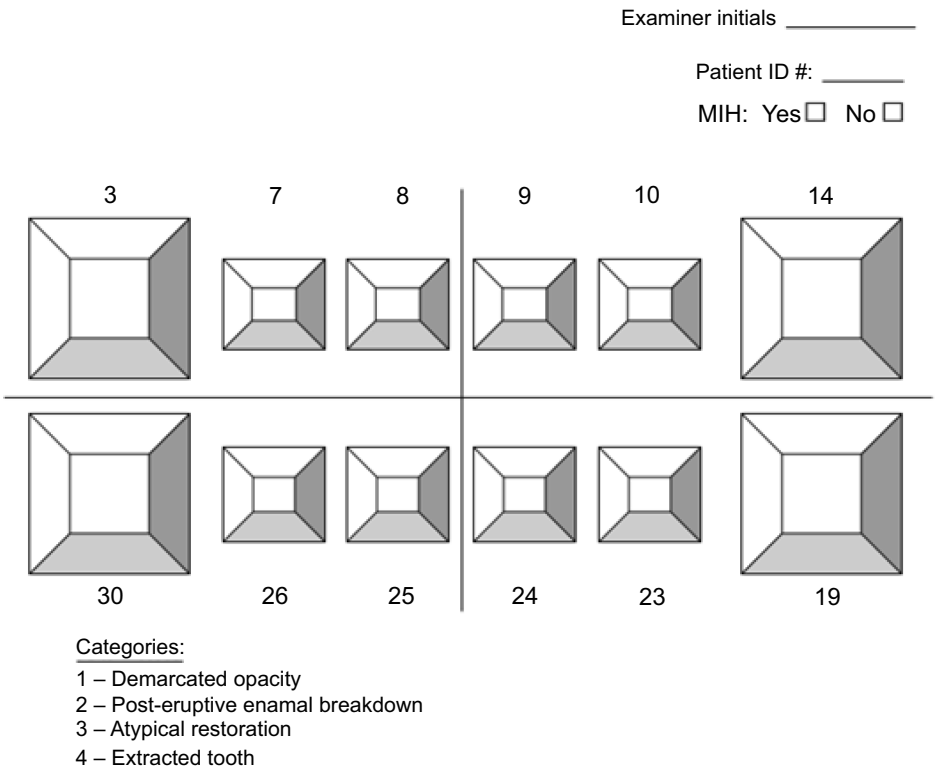

Figure 1 Each tooth surface with an MIH related finding was annotated with the corresponding category number listed in the legend.
Abbreviation: MIH - Molar-Incisor Hypomineralization.

assessment of these dental developmental defects. Inter- and intra-examiner agreement was very good (κ =0.93 inter-examiner agreement; 0.98 intra-examiner agreement).

Statistical analysis

Study sample size was calculated based upon the recommendation of Naing et al[14] Estimating a prevalence of 5% and level of confidence at 95% and a precision of 0.05 results in a sample size of at least 292 for good precision. Descriptive statistics were calculated including the frequencies for each variable collected. Bivariate analysis was done to identify factors associated with MIH based on a Pearson Chi-square test. All analyses were performed using SPSS statistical version 16.0 (International Business Machines, Armonk, NY). A statistically significant level (alpha) of $p<0.05$ was used throughout.

Results

Twenty-five schools with third grade students participated in the study yielding a potential study pool of approximately 1400 subjects. Between November 2014 and June 2015, 1304 consents were delivered to the schools, 387 consents were returned, and 375 students were screened for MIH (28.8% response rate). The average age of the students was 8.66 years (7–12 years) and the sample consisted of 60.3% females and 37.9% males (1.9% of returned forms did not report the sex of the child). Thirty-six out of 375 participants were found to have MIH, for a prevalence of 9.6% in our sample (95% CI of 6.62% - 12.58%). The demographic data of these children are summarized in Table 1.

Defects that were without enamel breakdown were considered mild, while any defect with post-eruptive breakdown, atypical restoration, or extraction were considered severe. Of the 36 cases positive for MIH, 25 (69.4%) were found to be mild and 11 (30.6%) were severe. Utilizing a Pearson Chi-square test, there were no statistically significant differences between MIH and gender (P=0.297), race (P=0.186), or income level (P=0.142), and the data is summarized in Table 2.

Out of the 36 patients affected, seventeen (47.2%) of them had involvement of only PFMs, while 19 (52.8%) had involvement of both PFMs and incisors. Involvement of incisors was more prevalent in cases where the PFM involvement was graded as severe (8/11 or 72.7%) than in cases where PFM involvement was graded as mild (11/25 or 44.0%) (Table 3). Of the 36 cases of MIH, 52.8% (19) had one PFM affected, 33.3% (12) had two PFMs affected, 5.5% (2) had three PFMs affected, and 8.3% (3) had all four PFMs affected. As more PFMs were affected, the defects tended to be more severe (ie all three of the cases with all four molars affected were diagnosed as having severe defects on at least one of the PFMs). The average number of surfaces per molar affected was 1.8. There were no cases of failure of eruption of a molar or incisor found.

Table 1 Distribution of subjects by sex, race/ethnicity, and socioeconomic status. Income distribution is based upon the 2014 US Department of Health and Human Services definition of the Federal Poverty Level (FPL) based on a family household consisting of 4 persons and reported in US dollars.[39] The first income level represents those families at or below the FPL. Each increase in income level represents a 50% increase in the FPL

Sex Distribution	
Male	142 (37.9%)
Female	226 (60.3%)
Not Reported	7 (1.9%)
Racial/Ethnic Distribution	
Hispanic	153 (40.8%)
African American	99 (26.4%)
Caucasian/Non-Hispanic	43 (11.5%)
Multiracial	35 (9.3%)
Asian	28 (7.5%)
American Indian/Alaskan Native	5 (1.3%)
Other	3 (0.8%)
Unknown/Not Reported	9 (2.4%)
Socioeconomic Distribution	
$0 - $23,850.00	199 (53.07%)
$23,851.00 - $35,775.00	67 (17.87%)
$35,776.00 - $47,700.00	28 (7.47%)
$47,701.00 - $59,625.00	10 (2.67%)
$59,626.00 - $71,500.00	13 (3.47%)
Above $71,550.00	31 (8.27)
Not Reported	27 (7.20%)

The maxillary PFMs had an overall higher prevalence (n=26) of MIH defects than the mandibular PFMs (n=18), but the lower PFMs had a higher frequency of severe defects (n=13) than the maxillary PFMs (n=5) when affected by MIH. The mandibular right PFM had a severe defect 42.1% of the time when affected, and the mandibular left PFM had a severe defect 41.7% of the time. The upper molars had fewer severe defects, with the maxillary right PFM being severely affected 20.0% of the time and the maxillary left PFM having a severe defect 12.5% of the time. The number of teeth and PFMs affected per subject are summarized in Table 3.

The average number of teeth affected per participant was 2.63 teeth. Prevalence per subject per tooth type of the MIH-positive cases is shown in Table 4. The mandibular right PFM had the highest percentage of MIH, affected in 19 cases

Table 2 Distribution of MIH by sex, race/ethnicity, and socioeconomic status

	Sex								Chi^2
	Male			Female					0.297
No MIH	131			201					
MIH Present	11			25					
Percent	7.7%			11.1%					
	Race/Ethnicity								
	Cauc	AA	Hisp	Asian	AI/AK	Multi	UK	Other	0.186
No MIH	42	86	135	24	5	35	1	3	
MIH Present	1	13	18	4	0	0	0	0	
Percent	2.3%	13.1%	11.8%	14.3%	0.0%	0.0%	0.0%	0.0%	
	Socioeconomic Status								
	1	2	3		4	5	6		0.142
No MIH	175	62	24		10	13	31		
MIH Present	24	5	4		0	0	0		
Percent	12.1%	7.5%	14.3%		0.0%	0.0%	0.0%		

Abbreviations: MIH, Molar-Incisor Hypomineralization; Cauc, Caucasian; AA, African American; Hisp, Hispanic; AI/AK, American Indian/Alaskan Native; Multi, Miltiracial; UK, Unknown; Other, Other race/ethnicity; Socioeconomic status, 1 (Federal Poverty Level (FPL))- $0–23,850.00, 2 (150% FPL)- $23,851.00-$35,775.00, 3 (200% FPL)- $35,776.00-$47,700.00, 4 (250% FPL)- $47,701.00-$59,625.00, 5 (300% FPL)- $59,626.00-$71,550.00, 6 (350% FPL) – above $71,550.00)[49].

Table 3 Severity and distribution of MIH defects

Severity	**Molars Only Affected**	**Molars and Incisors Affected**
Mild (25)	14 (56.0%)	11 (44.0%)
Severe (11)	3 (27.3%)	8 (72.7%)
Defects per PFM	**Mild**	**Severe**
Maxillary Right PFM (15)	12 (80.0%)	3 (20.0%)
Maxillary Left PFM (16)	14 (87.5%)	2 (12.5%)
Mandibular Left PFM (12)	7 (58.3%)	5 (41.7%)
Mandibular Right PFM (19)	11 (57.9%)	8 (42.1%)

Abbreviations: MIH - Molar-Incisor Hypomineralization, PFM - permanent first molar.

(52.8%). The maxillary left and right PFMs were the next most commonly affected teeth (16 cases each or 44.4%), followed by the mandibular left PFM (12 or 33.3%). The maxillary left permanent central incisor was the most commonly affected incisor (11 or 30.6%) followed by the maxillary right permanent central incisor (8 or 22.2%). The remaining permanent incisors ranged from none of the cases (0%, mandibular right permanent central incisor) to 5 of the cases (14%, maxillary left permanent lateral incisor) affected and the remaining data is summarized in Table 4.

Discussion

The aim of our pilot study was to determine the prevalence and severity of MIH in Milwaukee, Wisconsin. Our findings that nearly one in ten children are affected by this condition indicate that MIH is somewhat common amongst children in our sample. The prevalence of 9.6% is within the wide range of values seen in other studies across the world which ranged from 2 to 40% in a recent review article.[15] With no other studies published in the United States, it is not possible to directly compare our results to other US populations, however, a study published by Gurrusquieta et al[16] from Mexico reported a prevalence of 15.8%. Nonetheless, our prevalence is similar to others published from Lithuania,[17] Greece,[18] the Netherlands,[19] and Turkey.[20]

The difference in MIH prevalence between boys versus girls was not statistically significant. This finding is consistent with most studies that reported on sex differences[13,17–32] In addition there was no significant difference in terms of MIH severity by gender. However, Wogelius et al reported a greater prevalence of post-eruption breakdown and atypical restorations in girls than in boys (7.4% vs 4.2%).[33] Kemoli et al[34] and Jeremias et al[35] also reported that a higher prevalence of post-eruption breakdown and atypical restorations in girls. Ghanim et al found that boys had an increase in multiple molar involvement and greater post-eruptive breakdown than girls, but the difference was not significant.[36]

We found no statistically significant difference between the different race/ethnic groups analyzed,

Table 4 Frequency and distribution of MIH defects per subject and per tooth. It is possible that up to 12 teeth can be affected per subject, but no subjects had more than 8 teeth affected

Distribution of MIH Defects	
Number of teeth	**# of Subjects**
1	12 (33.3%)
2	8 (22.2%)
3	8 (22.2%)
4	3 (8.3%)
5	2 (5.6%)
6	2 (5.6%)
7	0 (0.0%)
8	1 (2.8%)
Number PFMs affected	**# of Subjects**
1	19 (52.8%)
2	12 (33.3%)
3	2 (5.6%)
4	3 (8.3%)
Prevalence per subject per tooth type	
Tooth type	**# of Subjects**
Maxillary Right PFM	16 (44.4%)
Maxillary Right Lateral Incisor	2 (5.6%)
Maxillary Right Central Incisor	8 (22.2%)
Maxillary Left Central Incisor	11 (30.6%)
Maxillary Left Lateral Incisor	5 (13.8%)
Maxillary Left PFM	16 (44.4%)
Mandibular Left PFM	12 (33.3%)
Mandibular Left Lateral Incisor	1 (2.8%)
Mandibular Left Central Incisor	4 (11.1%)
Mandibular Right Central Incisor	0 (0%)
Mandibular Right Lateral Incisor	1 (2.8%)
Mandibular Right PFM	19 (52.8%)

Abbreviations: MIH - Molar-Incisor Hypomineralization, PFM - permanent first molar.

which is consistent with the findings by Mahoney and Morrison[21] and Zagdwon et al[22], but different from Ng et al who found a greater prevalence in Malay children than Chinese children in Singapore.[23] Most reports did not separate out children according to racial or ethnic categories. The numbers of subjects self-identifying as multiracial was the fourth largest group in our study, with no cases of MIH. Although, socioeconomic status was not categorized in most studies, we found no statistically significant difference between different socioeconomic groups. This is consistent with findings by Mahoney and Morrison[21], Jeremias et al[35], and Oyedele et al[37]. However, Biondi et al[24], Balmer et al[38], Wuollet et al[39], and Lopez Jordi et al[40] found a higher prevalence of MIH in the higher socioeconomic cohorts while da Costa-Silva et al found MIH more prevalent in the lower SES cohort.[25]

The mean number of teeth affected by MIH in our study was 2.6 which is within the range of what has been reported, with a low of 1.98 (Soviero et al)[13] and a high of 5.7 (Lygidakis et al).[18] With respect to the arch most commonly affected, our study found a higher frequency in the mandibular arch, consistent with the findings of Mahoney and Morrison,[21] Jälevik et al[26], and Oyedele et al[37] However, other authors found the maxillary arch more commonly affected (Soviero et al[13], Lygidakis et al[18], Martinez-Gomez et al[27], Preusser et al[28], Kirthiga et al[29], Cho et al[30], Ghanim et al[36], Woullet et al[39], and Leppäniemi et al[41]). Still other studies demonstrated no differences between the arches (Weerheijm et al[19], Zagdwon et al[22], Ng et al[23], and Garcia-Margarit et al[42]). A possible reason for the differences found could be related to the fact that our study population was not recruited while they were seeking dental care at a clinic, as opposed to other studies that were conducted in a population seeking dental care.[31] It is quite possible that there would be higher prevalence of MIH in a population seeking dental care due to the increased sensitivity caused by MIH.

Given the unknown etiology of MIH and the wide genetic makeup of the multiple ethnic and racial backgrounds of the US population, our findings are not to be unexpected but also are difficult to interpret. The US is a nation of immigrants from all over the world and the prevalence of this condition worldwide varies from 2%[12] to over 40%.[13] As reported by Ng et al, many other publications may have been much more uniform in their ethnic and cultural makeup and therefore their findings can be expected to be extrapolated to that population much easier.[23] The study by Gurrusquieta et al[16] reporting a 15.8% prevalence rate may be a valid reference since the largest ethnic/racial group in our study self-identified as Hispanic. The lack of other studies from the US and Canada also make our data difficult to interpret but they may serve as a baseline from which to interpret larger studies.

For practitioners who care for a large number of children in Milwaukee, the clinical relevance of these findings indicates that approximately one in every ten children they see may have a molar affected by MIH. Since these teeth are extremely difficult to profoundly anesthetize, adjunctive pain control measures may need to be employed. Alternative pain control measures may include the use of nitrous oxide, mild to moderate sedation, and/or general anesthesia.[43] These adjunctive measures require the appropriate delivery and monitoring equipment or staff privileges at local hospitals in order to safely, effectively and efficiently deliver the required care.[44] Payers for these

services need to have adequate, current prevalence data to support the medical necessity of delivering and reimbursing these adjunctive pain control measures when clinically indicated.[11] Restorative options for treating teeth affected by MIH vary with the severity of the defects. Defects without PEB may be sealed, but any cavitation or PEB may indicate a restoration, while extensive breakdown may necessitate endodontic therapy and or extraction. The reader to directed to an article published by Ghanim et al[45] which expertly summarizes the array of treatment options available to treat MIH-affected teeth.

Certain limitations must be noted. First, it is not possible to generalize our findings to the whole population of children in MPS in Milwaukee. However, our findings are representative of the study population. In addition, our study had a high prevalence of Hispanic participants (40.8%, compared to 24.6% Hispanic prevalence reported by the MPS system[46]) or for the City of Milwaukee which reports a Hispanic population of 17.3%.[47] We may have seen a higher percentage of Hispanic participants due to a higher involvement of schools affiliated with school-based sealant programs. Many of these schools are in Latino neighborhoods where there are existing relationships between the school and the university researchers. Therefore, these schools and their students/parents may have been more inclined to participate in our study. Many of the residents of Milwaukee who are of Hispanic origin immigrated here from Mexico and the report by Gurrusquieta et al[16] indicated a 15.8% prevalence of MIH their study population in Mexico City, which may have inflated our findings.

Another potential limitation of our study is the small sample size compared to the whole Milwaukee children population or samples from other reported studies. Reported sample sizes in the literature range from a low of 102[48] to 4989.[31] Of the studies referenced, five authors had participant numbers lower than ours (102–307),[13,20–22,48] one had a number very similar (378),[32] and the remaining reports[12,17–19,23–31,33–42] had numbers greater than ours (469–4989). This study intended to examine approximately 1000 third grade students in the MPS system but was only able to recruit the 375 patients reported. Regulations within the MPS system authorizes individual schools to elect to or decline to participate in research studies such as this one. Despite our request to have access to contact the approximately 4000 third grade students attending 108 schools, only 25 schools elected to participate, reducing the patient pool to approximately 1300 students. Anticipating a 30% response rate to our recruitment letters, this would result in a subject number of 390. As recommended by Naing et al[14], the appropriate sample size for an expected prevalence of 5% in a population is 292 while a prevalence of 10% would only need approximately 200 subjects. Thus, Elfrink et al[50] recommended that a valid sample size for prevalence studies in MIH be at least 300 subjects.

Conclusions

Based on this investigation's results, the following conclusions can be made:

1. The prevalence of MIH in this cohort of third grade students in Milwaukee, WI was 9.6%.
2. These findings are within the range reported for other countries and can be regarded as a valid baseline for further comparison for subsequent studies.
3. MIH is a concerning developmental dental concern in our area, and more studies are warranted to further estimate and analyze the prevalence, characteristics, and impact that MIH is having both in our state as well as throughout the United States.

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Author contributions

All authors contributed to data analysis, drafting or revising the article, gave final approval of the version to be published, and agree to be accountable for all aspects of the work.

Disclosure

The authors report no conflicts of interest in this work.

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