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ORIGINAL SCIENTIFIC ARTICLE

Prevalence and severity of molar-incisor hypomineralization, is there an association with socioeconomic status? A cross-sectional study in Chilean schoolchildren

D. Harz[1] · B. Catalán Gamonal[2] · S. Matute García[2] · F. Jeremias[3] · J. Martin[4] · M. C. Fresno[2]

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Abstract

Purpose Data about molar-incisor hypomineralization (MIH) prevalence and its severity remains limited for some Latin American countries. Furthermore, its association with socioeconomic status (SES) is still unclear. Thus, this study aims to determine the prevalence and severity of MIH in Santiago, Chile and explore its association with SES.

Methods A cross-sectional study with schoolchildren between 6 and 12 years was conducted. Children were evaluated using the European Academy of Paediatric Dentistry to diagnose MIH, and the Mathu-Muju and Wright criteria to determine its severity.

Results A total of 1,270 children were included. The MIH prevalence was 12.8% without association with gender ($p=0.609$). Prevalence was higher among schoolchildren ages 8 and 9 ($p=0.002$), and in lower SES ($p=0.007$). MIH mild cases were the most prevalent (63%), and severity was not related to gender ($p=0.656$), age ($p=0.060$), or SES ($p=0.174$).

Conclusions The prevalence of MIH in the province of Santiago, Chile is 12.8% and was found to have a higher incidence in 8–9-year-old students and among those categorized by low SES. Furthermore, MIH prevalence was associated with low SES.

Implications Public health policies to address MIH in Chile should start with schoolchildren aged 8 to 9, and with low SES.

Keywords Molar incisor hypomineralisation · Molar incisor hypomineralization · MIH · Prevalence · Severity · Socioeconomic status

Introduction

Molar-incisor hypomineralization (MIH) has been traditionally defined as a qualitative defect of the enamel that affects the first permanent molars (FPM) with or without the involvement of the permanent incisors (Weerheijm 2003; Lygidakis et al. 2010). Similar lesions involving second primary molars (Elfrink et al. 2012) and other permanent teeth have also been described (Schmalfuss et al. 2016). Because of its association with the development of caries, tooth fracture, tooth loss, and its detrimental impact on children's and adolescents' quality of life and fear of dental attention, MIH has been recognized as a significant oral pathology and thus needs to be addressed with urgency (Bandeira Lopes et al. 2021; Jälevik et al. 2021). Nevertheless, due to its complex etiology, the approach to handle this pathology is limited to early detection and treatment only, without any possibility of preventing its appearance (Wuollet et al. 2016; Silva et al. 2016; Serna et al. 2016; Vieira and Kup 2016).

The prevalence of MIH has shown to be highly variable globally ranging from 2.4% to 40.2% (Hernandez et al. 2016; Bandeira Lopes et al. 2021). Moreover, data available from Latin America and specifically in Chile are scarce. Regarding the latter, 2 articles have reported MIH prevalence in Chile corresponding to 14.1% (Vallejos Reyes and Jiménez Del Río 2010) and 16.8% (Jans Muñoz et al. 2011).

✉ M. C. Fresno
mcfresno@odontologia.uchile.cl

1 Dental School, Pontificia Universidad Católica de Chile, Santiago, Chile

2 Faculty of Dentistry, University of Chile, Santiago, Chile

3 Graduate Program in Dental Science Araraquara School of Dentistry, UNESP Univ Estadual Paulista São Paulo, Araraquara, São Paulo, Brazil

4 Department of Restorative Dentistry, Faculty of Dentistry, University of Chile, Olivos 943, Independencia, Santiago, Chile

Unfortunately, these studies used small samples that were non-generalizable and non-randomized; thus, the results are limited. An additional study from Corral-Núñez et al. (2016) published preliminary data from the present project itself, finding a prevalence of 12.7%.

Finally, the association between MIH and socioeconomic status (SES) is still unclear, which adds another layer of complexity to the prevention and treatment of MIH among those most vulnerable and susceptible. Some previous studies have explored this association and reported mixed findings. Ahmad et al. (2019) and Balmer et al. (2012) found a positive correlation, while Reis et al. (2021) did not find any association. Furthermore, these results are unreliable as the studies have some major methodological flaws.

This project aims to determine the prevalence and severity of MIH in schoolchildren of the Santiago province and explore its association with SES.

Methods

This study is part of a larger epidemiological project that sought to determine MIH, caries, and fluorosis prevalence, and their clinical implications, in 6–12-year-old schoolchildren from the Santiago province, Chile (FONIS-CONICYT SA14ID0056).

Study population

This cross-sectional study included a population of schoolchildren between 6 and 12 years, who attended public or private schools in the Santiago province and were registered in the Regional Secretary of the Educational Ministry's database. The Santiago province is a regional administrative and territorial subdivision of the cities in Chile and corresponds to 1 of the 6 provinces of Chile's Metropolitan Region. It is the most populated province of the country and is subdivided into 32 communes.

The sampling approach considered an alpha level of 0.95 and a precision of 3% for the prevalence estimation as significant. A 50% estimate proportion was applied, requiring 1332 schoolchildren, based on the 745,440 schoolchildren aged 6 to 12 within the province (Censo 2002), and considering a 20% replacement rate.

The sampling design was randomized, probabilistic, proportional stratified, and multi-staged. It was based on the province, educational institution, number of people selected per commune, and number of people selected by age and gender (Fig. 1).

Student SES was classified as low, middle, and high based on data from the 2015 CASEN (Social Economic Characterization Survey) of the school location (commune) that each student attended (Metropolitana 2015).

The sampling process was performed in 3 stages: (1) stratified selection based on SES of the communes, determining the communes to be included for the sampling; (2) randomized selection of the private and public schools of the communes selected in the first stage; and (3) participant selection, children of the previously selected schools that met the inclusion criteria and did not present any exclusion criteria. Inclusion criteria were schoolchildren between 6 and 12 years of age, with all FPM erupted, who were willing

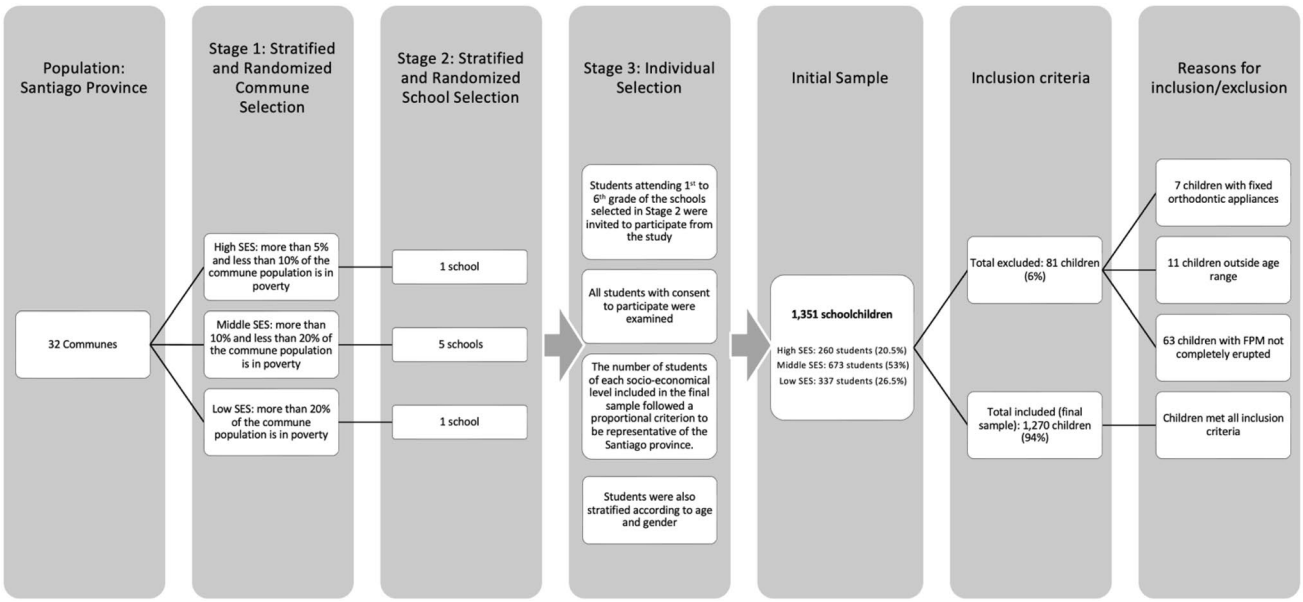

Fig. 1 Flowchart summary of sampling process of schoolchildren of the province of Santiago in Chile, $n = 1270$

to voluntarily participate, and whose parents accepted and signed the informed consent. Children 11 years or older were also asked to sign an informed assent. Exclusion criteria were individuals with dental enamel defects related to syndromes, severe dental fluorosis, amelogenesis imperfecta, and/or the presence of fixed orthodontic appliances.

Intraoral examination

The clinical exam was performed at the selected schools by 2 calibrated examiners, with an inter-rater and intra-rater reliability, kappa value of 0.94. The evaluations were performed under natural light, with the aid of an oral mirror number 5, the World Health Organization (WHO) recommended probe, and an additional LED Headlamp Flashlight (Energizer®).

The following data were documented: (1) MIH presence, based on the judging criteria for MIH of the European Academy of Paediatric Dentistry (EAPD) (Weerheijm et al. 2003); and (2) severity, following the Mathu-Muju and Wright criteria 2006. See Online Appendix 1 for a detailed description.

This study was approved by the Dental School of the Universidad de Chile's ethics committee (Approval Act number N° 9, dated November 20th, 2014) and followed the Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) guidelines for its report (Von Elm et al. 2007).

Attending to an ethical responsibility, patients included in the study that were diagnosed with MIH were offered free dental treatment at the Dental School of the Universidad de Chile.

Analysis

Data were analyzed using univariate descriptive statistics for MIH prevalence and severity. The association between MIH prevalence and severity with age, gender, and SES was determined using Fisher exact test and logistic regression with a 5% significance level. All statistical analyses were performed with the statistical software STATA (StataCorp. 2019. Stata Statistical Software: Release 16.).

Results

Data collection was performed between April 2015 and October 2016. A total of 7 schools in the Santiago province were visited following the proportional sampling: 1 high SES school, 5 SES middle schools, and 1 low SES school. Initially, 1351 schoolchildren were recruited and evaluated clinically, from which 81 were excluded based on the inclusion and exclusion criteria: 7 were using fixed orthodontic appliances, 11 were outside the age range, and 63 did not have their FPM completely erupted. Hence, a total of 1270 schoolchildren were included in the study (Fig. 1).

The univariate descriptive statistics for the sample characteristics are presented in Table 1. There were no missing data in the sample. The mean age was 9.03 years (SD = 1.2), with a minimum age of 6 years and a maximum of 12 years. The total number of students identified as females was 651 (51.3%), while 619 students (48.7%) identified as males. Regarding SES, the final sample aligned with the proportional criteria and representativeness: 260 students (20.5%) came from a high SES school, 673 students (53%) from middle SES schools, and 337 (26.5%) from low SES schools (Fig. 1).

The prevalence of MIH was 12.8%, with no significant difference between gender ($p = 0.609$) (Fig. 2). Concerning age, a higher prevalence of MIH was found among children 8 and 9 years ($p = 0.002$), even when controlling for SES, with an OR of 1.7 (Fig. 3).

Regarding SES, we found a significant difference in MIH prevalence between high and low SES ($p = 0.007$) even when controlling for age, with an OR of 2.08 for lower SES (Fig. 4).

When analyzing severity, mild MIH was the most prevalent condition (63%), followed by severe (22.8%) and moderate cases (14.2%). No significant difference was found by gender ($p = 0.656$), SES ($p = 0.174$), or age ($p = 0.060$) (Figs. 2, 3, and 4, respectively).

Discussion

The present manuscript reports some of the results of a larger project—one of the few studies developed in Chile and the first that employed a randomized and representative sample of the Santiago province. Here, we describe the prevalence and severity of MIH of the larger sample and outline the association between MIH prevalence and SES. A previous publication from our group, that used the larger project data, focused on the correlation of caries and MIH (Corral-Núñez et al. 2016).

Table 1 Descriptive statistics of schoolchildren over age, gender, and SES; from a random, proportional stratified, and multi-staged sample of schoolchildren of the province of Santiago in Chile, $n = 1270$

Variable	Intervention *n* (%)
Age, mean (SD)	9.03 (1.24)
Gender	
Female	651 (51.3)
Male	619 (48.7)
SES	
Low	337 (26.5)
Middle	673 (53.0)
High	260 (20.5)

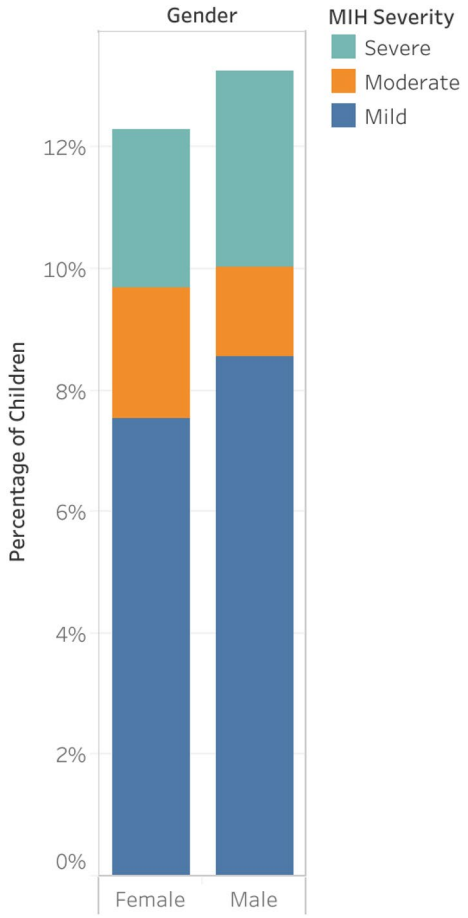

Fig. 2 Prevalence of MIH by gender in a sample of schoolchildren of the province of Santiago in Chile, $n = 1270$

Our study reports a prevalence of 12.8% MIH cases in schoolchildren aged 6 to 12, slightly lower than the previous 14.1% (Vallejos Reyes and Jiménez Del Río 2010) and 16.8% (Jans Muñoz et al. 2011) reported in Chile.

Our results are within the global range of 2.3–40.2% described in the literature (Bandeira Lopes et al. 2021; Hernandez et al. 2016) and very similar to the mean global prevalence reported by 2 recent systematic reviews and meta-analyses: 14.2% (8.1–21.1%) (Dave and Taylor 2018) and 12.9% (11.7–14.3%) (Schwendicke et al. 2018).

When comparing our findings to studies completed in South and North America, that also used the EAPD criteria, these are fairly similar: 12.3% and 16.1% in Brazil (Jeremias et al. 2013; Raposo et al. 2019); 15.9% and 16.1% in Uruguay and Argentina, respectively (López Jordi et al. 2014); 15.8% in Mexico (Gurrusquieta et al. 2017); 12.4% in Canada (Sidhu et al. 2020); and a range between 9.6% (Davenport et al. 2019; Hartsock et al. 2020) and 13% (Ahmed et al. 2020) in the United States.

When comparing our results with the prevalence of the rest of the world, we found a higher prevalence than in Africa (10.3% global) (Bandeira Lopes et al. 2021), but comparable to some Asian countries, such as India (13.9%) (Mishra and Pandey 2016) and Singapore (12.5%) (Ng et al. 2015). Nevertheless, other studies have found much higher prevalence rates; Australia has reported values as great as 44% (Jälevik 2010), Brazil 40.2% (Soviero et al. 2009), Greece 21% (Kevrekidou et al. 2015), and Japan up to 28.1% (Saitoh et al. 2018). This ample range in prevalence and variance between countries has been attributed to the use of diverse study designs (Hernandez et al. 2016). Study designs differ on the age ranges and sample sizes included, lack of examiner calibration, different data collection methodologies, and type of MIH diagnosis and severity criteria employed (Hernandez et al. 2016). Regarding the latter, it has been shown that studies using the EAPD definition and criteria diagnosis could report a higher prevalence when compared to other methodologies (Bandeira Lopes et al. 2021). Therefore, comparing prevalence data from different countries should be handled with caution.

Our results also showed a significantly higher MIH prevalence in 9- and 8-year-old children ($p = 0.002$). These results support the EAPD recommendation of MIH diagnosis at 8 years when all FPMs and incisors have erupted, and any damage to the hypomineralized enamel is limited, while the signs of MIH are still visible (Weerheijm et al. 2003).

Regarding the MIH prevalence and SES, we found an association between these variables, whereby schoolchildren of lower SES presented a significantly higher prevalence of MIH. When compared to schoolchildren of a higher SES, schoolchildren from low SES were 2.08 times more likely to present MIH (OR = 2.08).

Our results aligned with both the studies published by Ahmad et al. (2019) and Balmer et al. (2012); nevertheless, these earlier studies did not use the EAPD criteria to diagnose MIH. It has been shown that EAPD diagnostic criteria could report a higher prevalence when compared to other methodologies, thus affecting the previous studies' outcomes (Lygidakis et al. 2010) that could be inaccurate. Meanwhile, a recent study by Reis et al. (2021) that used EAPD criteria found no correlation between MIH prevalence and SES variables. Nevertheless, the socioeconomic variables were not combined to define participants' SES as a construct and stratify them by SES categorization. Therefore, these results must be read with caution. Thus, our results prove useful to solve these inconclusive and perhaps even unreliable outcomes, by finding an association between low SES and higher MIH prevalence, when compared to a high SES.

This association between MIH and SES could be supported by the existing correlation between some early systemic conditions and MIH (Garot et al. 2022), and in turn, a connection between low SES and poorer physical health (Spencer et al. 2013). Childhood illnesses presented in early infancy—such as measles, urinary tract infection, bronchitis,

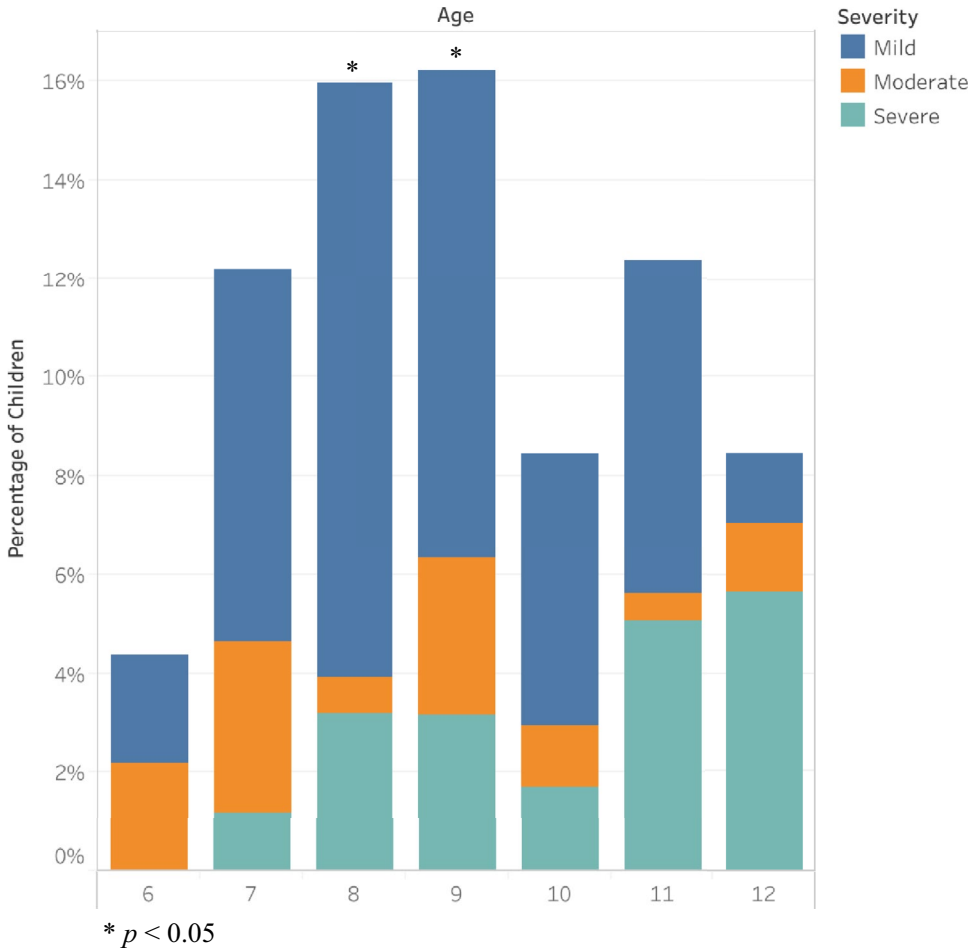

Fig. 3 Prevalence and severity of MIH by age in a sample of schoolchildren of the province of Santiago in Chile, $n = 1270$

otitis, gastric disorders, fever, kidney diseases, pneumonia, and asthma—and the use of antibiotics have been associated with the development of MIH (Garot et al. 2022). It has been suggested that these systemic conditions could alter the calcification of FPM and incisors by impacting the functions of specific enzymes and cells, and shifting the pH levels during the odontogenesis process (Silva et al. 2016).

Specifically, regarding SES and childhood illness, a systematic review concluded that SES is associated with poorer health status, acute and recurrent infections, and an increase in hospitalization (Spencer et al. 2013). This also applies to the Chilean context, where multiple studies have also reported a direct association between respiratory and other infectious diseases in early childhood, and SES (Rivas et al. 2011). Hence, the higher prevalence of MIH in low SES found in our study could be explained by a possibly higher prevalence of respiratory diseases during the critical period of enamel calcification in this group of children.

Furthermore, our results could be compared with those of other studies suggesting that different living settings could have an impact on the development of MIH. Da Costa-Silva et al. (2010) analyzed the difference in the prevalence of MIH between the rural and urban populations, and found a significant difference between them, suggesting that diverse living settings could have an impact on the development of this pathology, because of reduced access to public health services. These results support our findings associating MIH prevalence and SES. Although our study only included an urban population, students in the lower SES could resemble the rural Brazilian population, since this group presents a lower SES in that country (Souza et al. 2019). Moreover, a study by López Jordi et al. (2014) compared the prevalence of this dental pathology considering patients' type of dental care (public vs. private) and found a higher prevalence of MIH in patients treated in the public setting, setting that for the Argentinian context is considered to be used by the lower SES population (López Jordi et al. 2014).

The importance of our findings regarding the association between MIH prevalence and SES is mainly related to public health policies, where economic and human resources should focus on the most affected population initially to have a bigger impact. Thus, we recommend that in the Santiago province of Chile, public health measures should be centered initially on children aged 8 to 9, from lower SES communities.

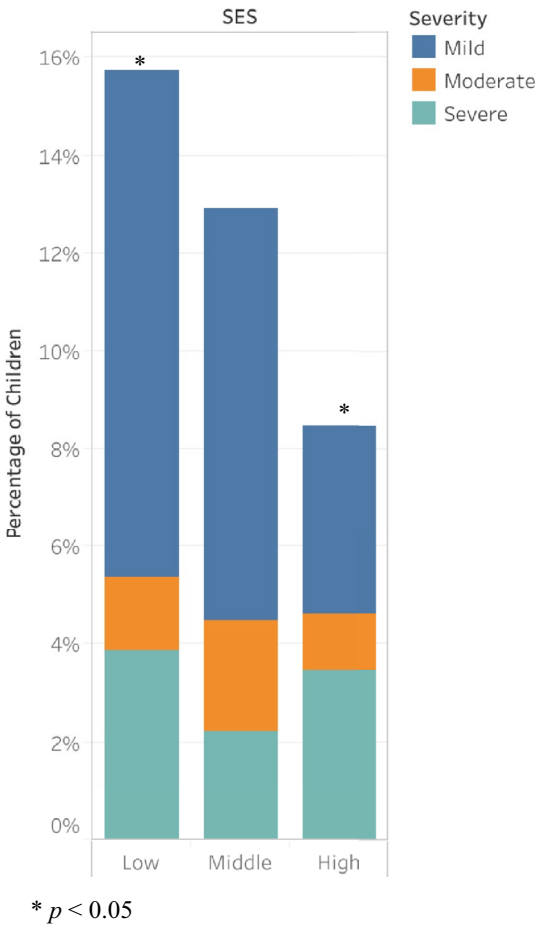

Fig. 4 Prevalence and severity of MIH over SES in a sample of schoolchildren of the province of Santiago in Chile, $n = 1270$

Regarding severity distribution and SES, our study did not find significant differences between the strati. Moreover, the severity pattern was similar for all SESes. Currently, there are no studies that explore these variables; consequently, there is a need for more research in this area.

When analyzing MIH severity and age, our findings showed no association, which contrasts with previous studies (Bhaskar and Hegde 2014). This difference could be explained by the fact that our sample included students up to 12 years. The older the child, the more time has passed since an MIH-affected tooth's eruption; hence, the higher the possibility to become more damaged or developing caries, and consequently become restored. This could translate to MIH-affected teeth having been diagnosed as filled rather than affected by MIH, which may have impacted the association between severity and age. This premise could also explain why we found a higher MIH prevalence in 8- and 9-year-old children that is not sustained in 10–12 years.

Although these results are promising, the findings presented in this study have some limitations. First, data for our study was gathered between 2015 and 2016. Nevertheless, public health policies regarding MIH have not changed since then. Therefore, our results are still relevant and representative of the current situation of MIH in the Santiago province of Chile. Second, although our sample was representative of the most populated province of the country, it is not representative of Chile's population altogether. Furthermore, the sampling technique did not consider any Chilean ethnic representativeness nor ponder the migrant population. Hence, the results of this study are generalizable only to the Santiago province schoolchildren or similar populations. Therefore, we suggest increasing the efforts to determine its prevalence nationwide, including people from all ethnic backgrounds that inhabit Chile, comparing the urban and rural settings, and between the different SES groups. Based on our results about MIH and SES, we recommend developing international studies with an emphasis on the relation between these variables to assess their association globally.

In addition, SES was determined based on the type of schools attended by the students, which could have miscategorized some few participants. However, Chile's educational system is unique, because it is characterized by a pronounced level of segregation (González 2017); thus—in general—public schools tend to concentrate on the most socially disadvantaged students, the middle–low and middle class attend private-subsidized schools and the high class goes to private schools (Hascoët et al. 2021; Treviño et al. 2016). Therefore, in Chile, the school SES characterization has been shown to be a reliable and widely used SES indicator (Mena et al. 2021), and has been previously used when studying MIH in this specific country (Gambetta-Tessini et al. 2019). Nevertheless, although the use of school type as an indicator for SES is valid in Chile it may not necessarily apply to other countries. Therefore, we recommend that future studies include other SES indicators or even use a compound characterization.

Finally, MIH severity was determined using the Mathu-Muju and Wright criteria that could add more detailed information by including a 'moderate' level between the 'mild' and 'severe' MIH severity categories used in the EAPD criteria (Lygidakis et al. 2010). Nevertheless, currently, the most frequently used approach to diagnose MIH severity is the latter (Lygidakis et al. 2021). Therefore, comparing our findings with recent studies that use the EAPD criteria could entail some limitations.

Conclusion

Our findings show that MIH is a dental pathology with a high prevalence (12.8%) in the Santiago province's schoolchildren and has a higher incidence in 8–9-year-old students. MIH prevalence was associated with low SES, by which

schoolchildren of lower SES presented a significantly higher prevalence of MIH when compared to high SES.

Supplementary Information The online version contains supplementary material available at https://doi.org/10.1007/s40368-023-00820-3.

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Data availability The data that support the findings of this study are available from the corresponding author, MCF, upon reasonable request.

Declarations

Conflict of interest Dominique Harz, has no relevant financial or non-financial interests to disclose. Braulio Catalán Gamonal has no relevant financial or non-financial interests to disclose. Stephanie Matute García has no relevant financial or non-financial interests to disclose. Fabiano Jeremias has no relevant financial or non-financial interests to disclose. Javier Martin has no relevant financial or non-financial interests to disclose. Maria C. Fresno has no relevant financial or non-financial interests to disclose.

Ethics approval This study was approved by the Dental School of the Universidad de Chile's ethics committee (Approval Act number N° 9, date November 20th, 2014).

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

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