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Prevalence and Geographic Distribution of Molar-Incisor Hypomineralisation in Spain: A Systematic Review and Meta-Analysis



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Abstract

Aim To systematically evaluate the prevalence of molar-incisor hypomineralisation (MIH) among Spanish children and adolescents and to investigate methodological and geographical factors contributing to the variability of prevalence estimates.

Materials and Methods A systematic review and meta-analysis was conducted according to the PRISMA 2020 guidelines and prospectively registered in PROSPERO (CRD420261411600). PubMed, Scopus, Embase, Ovid MEDLINE, CINAHL and grey literature sources were searched. Cross-sectional studies reporting MIH prevalence in Spanish children aged 6–18 years were included. Study quality was assessed using the Joanna Briggs Institute Critical Appraisal Checklist for Prevalence Studies. Pooled prevalence estimates were calculated using random-effects logistic regression models. Subgroup analyses, meta-regression and sex-specific analyses were performed to explore sources of heterogenerity.

Results Thirteen studies comprising 15 independent samples and 6,978 participants met the inclusion criteria. The pooled prevalence of MIH in Spain was 17.6% (95% CI: 14.0–21.9), although considerable heterogeneity was observed (I^2=93.9%). Individual study prevalence ranged from 7.0% to 31.4%. Clinical samples showed higher prevalence than population-based studies, while meta-regression demonstrated a significant inverse association between age and MIH prevalence (OR=0.86 per additional year; 95% CI: 0.77–0.96; p=0.007). No significant differences were observed according to sex, publication year or study setting. Marked geographical variability was identified, with higher prevalence reported in Madrid and southwestern Andalusia than in Catalonia. Most included studies presented low-to-moderate risk of bias, although inconsistencies in examiner calibration and diagnostic procedures remained important methodological limitations.

Conclusions Approximately one in six Spanish children is affected by MIH, placing Spain among the European countries with the highest reported prevalence. Significant geographical variation and methodological heterogeneity persist, highlighting the need for standardized diagnostic protocols and nationally representative epidemiological studies to improve comparability and support preventive oral health strategies.

KEYWORDS Molar-incisor hypomineralization; MIH; prevalence; systematic review; meta-analysis; Spain; paediatric dentistry.

INTRODUCTION

Molar Incisor Hypomineralisation (MIH) currently represents one of the most prominent qualitative enamel defects in paediatric dentistry, primarily due to the increasing number of cases observed in clinical practice over recent decades [Mast et al., 2013, Lygidakis et al., 2022]. This developmental dental defect must affect at least one of the first permanent molars and, to a lesser extent, the permanent incisors [Weerheijm, 2003]. Clinically, it manifests as demarcated enamel opacities varying in colour from white to yellow or brown [Bandeira et al., 2021]. The disturbance occurs during the maturation phase of amelogenesis, resulting in enamel with reduced mineral content. Consequently, the affected tooth becomes highly susceptible to post-eruptive breakdown (PEB) once it enters occlusal function [Mast et al., 2013, Lygidakis et al., 2022, Weerheijm, 2003, Bandeira et al., 2021].

The clinical significance of this entity stems not only from the structural fragility of the compromised enamel but also from the severe dentine hypersensitivity experienced by some of these patients, which complicates both oral hygiene and the execution of restorative and anaesthetic procedures [Hjertberg et al., 2025]. As a result, affected teeth exhibit a high predisposition to early-onset, rapidly progressing carious lesions, despite the aetiopathogenesis of the disorder being distinctly unrelated to dental caries. Furthermore, restorations placed in these teeth often demonstrate reduced longevity owing to the substandard mechanical properties of the hypomineralised enamel matrix [Inchingolo et al., 2023]. Scientific interest in this pathology began to solidify in the 1980s, when clinicians from the Swedish Public Dental Service reported an unusual surge in children presenting with severe enamel defects of unknown origin in their first permanent molars and incisors [Koch et al., 1987]. Subsequently, in 2001, Weerheijm coined the term "Molar Incisor Hypomineralisation" to formalise this systemically driven condition. Later on, the European Academy of Paediatric Dentistry (EAPD) established standardised diagnostic criteria, which specify the presence of demarcated opacities larger than 1 mm as an essential criterion, whereas post-eruptive enamel breakdown, atypical restorations, and the premature extraction of affected molars may or may not be present depending on clinical severity [Lygidakis et al., 2022, Weerheijm, 2003]. Despite extensive research, the aetiology of MIH remains elusive and is widely considered multifactorial. Various authors have linked its onset to systemic factors acting during the prenatal (e.g., maternal fever, medication use, or hypoxia), perinatal (e.g., prematurity, low birth weight, and complications during delivery), and early postnatal periods (e.g., recurrent febrile episodes, respiratory tract diseases, intake of specific antibiotics, vitamin D deficiency, exposure to environmental pollutants, and bisphenol A) [Lygidakis et al., 2022, Silva et al., 2016]. Given its rising prevalence and the subsequent diagnostic and therapeutic hurdles it poses, MIH stands as a major clinical and scientific challenge today, underscoring the critical need to deepen our understanding of its aetiological factors, diagnostic modalities, and management alternatives. With these considerations, epidemiology emerges as a cornerstone element that must be taken into account. Epi-

demiology constitutes the fundamental pillar of public health, as it allows for the transformation of individual clinical observation into collective and quantifiable knowledge. It not only measures the frequency and distribution of diseases within a population, but also identifies patterns, temporal trends, and risk groups. Within MIH, epidemiology is crucial as it allows for the determination of the real scope of the defect (prevalence and severity) across different regions. This is vital because MIH varies drastically between populations, with reported figures ranging from less than 3% to more than 40% [Lygidakis et al., 2022, Mazur et al., 2023].

Epidemiological studies help establish critical windows of risk that serve as clinical predictors to anticipate the onset of MIH in the permanent dentition. By quantifying how many children suffer from the most severe forms (defined according to EAPD severity criteria as presenting with post-eruptive enamel breakdown, severe hypersensitivity, and rapid caries progression), epidemiology provides the necessary data for public health systems to adapt their paediatric dental care programmes and therapeutic resources [Lygidakis et al., 2022].

When the exact cause of a pathology remains unclear (as is currently the case with MIH, where it is only known to be of multifactorial and systemic origin) this area ceases to be merely a measurement tool and becomes a tool for aetiological diagnosis. It allows us to formulate hypotheses: by recording the clinical-epidemiological characteristics of affected children and cross-referencing them with their medical history (pre-, peri-, and postnatal events during the first years of life), enabling the association of patterns. If an environmental or medical factor (such as the use of certain antibiotics, high fevers, or neonatal hypoxia...) appears with a significantly higher frequency in the MIH group, a warning sign is raised [Lygidakis et al., 2022, Bandeira et al., 2021, Silva et al., 2016].

It also allows for the controlling of confounding variables: it enables the isolation of variables, and even if the exact biological cause is unknown, discovering through epidemiology which profiles or stages of child development are most strongly associated with the defect allows professionals to establish early secondary prevention strategies (such as applications of high-concentration fluorides or sealants before the tooth fractures), thereby minimising the sequelae of a pathology that we cannot yet prevent from appearing [Garot et al., 2018].

Consequently, in the absence of an established single cause for MIH, conducting local epidemiological studies that analyse clinical characteristics and prevalence in specific cohorts is not only pertinent but strictly necessary. This study was conducted with the objective to determine the prevalence of MIH within the Spanish child and adolescent population, whilst analysing its geographical distribution, clinical characteristics, and associated factors.

METHODS

This systematic review and meta-analysis was conducted and reported in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) 2020 guidelines. The study protocol was previously registered on the International Prospective Register of Systematic Reviews (PROSPERO) with the code: PROSPERO 2026 CRD420261411600.

Selection Criteria

We included observational studies published between 1 January 2006 and May 2026 that examined the prevalence of MIH in the Spanish population. The studies had to meet the following criteria: cross-sectional or cohort design; Spanish participants or long-term residents in Spain (defined as children enrolled in local school/healthcare systems for at least 1 year prior to the study assessment); assessment of the prevalence of MIH; publication in Spanish, English, Basque, Catalan, Galician, or Valencian; and definition of the criteria used to define MIH. Case-control studies were also excluded. The context in which the study was conducted was also considered, since research carried out in clinical settings differs from population-based studies conducted in schools and could tend to overestimate the prevalence of MIH. Study settings were categorised into three groups: (1) School-based, conducted within primary/secondary schools; (2) Clinical/dental, conducted in outpatient university clinics or hospital dental units; and (3) Population- or community-based, defined as epidemiological surveys utilising regional public health registries, census data, or non-clinical municipal health centres representative of the general paediatric population.

PI(E)CO QUESTION

P (Population): Spanish children and adolescents aged 6 to 18 years. I (Intervention/Exposure): Residence within distinct geographical settings in Spain (analysed at the level of Autonomous Communities—e.g., Catalonia, Madrid, Valencia, Andalusia, Asturias—as well as specific provinces or municipalities). C (Comparison): Prevalence of MIH across different Spanish regions, as well as comparison against the global prevalence. O (Outcome): Prevalence of MIH. Formulated PI(E)CO Question: "What is the prevalence of Molar Incisor Hypomineralisation among Spanish children and adolescents aged 6 to 18 years across different geographical regions?"

Sources of Information

A literature search was performed across the PubMed, Scopus, Embase, Ovid MEDLINE, and CINAHL databases, covering the period from 1 January 2006 to May 2026 (when searches were completed). The search strategy incorporated keywords and Medical Subject Headings (MeSH) terms related to 'Molar Incisor Hypomineralisation', 'MIH', and 'Spain', supplemented by additional terms identified through preliminary scoping searches. Furthermore, preprint registries and the reference lists of all eligible articles were hand-searched. Grey literature was systematically searched using Google Scholar, the Spanish national doctoral thesis database (TESEO), Dialnet, and institutional repositories of Spanish public universities offering dental degrees (e.g., University of Seville, Complutense University of Madrid, University of Valencia, University of Barcelona, amongst others) using standard Spanish search terms ('hipomineralización incisivo molar', 'prevalencia'). Search strategies were tailled to the specific syntax and characteristics of each database. These strategies were developed by combining controlled vocabulary (e.g., MeSH and Emtree terms) with free-text terms, using Boolean operators (AND/OR), truncation (asterisks...), and wildcards. Document retrieval was restricted to studies published in the specified languages within the 2006–2026 search period. To ensure the comprehensive identification of all observational studies meeting the eligibility criteria, no study-design filters were applied. The detailed search strategy for PubMed/MEDLINE was as follows: ('molar incisor hypomineralisation' OR 'MIH' OR 'developmental enamel defects') AND ('prevalence' OR 'epidemiology') AND ('Spain' OR 'Spanish'). Complete search strategies for all electronic databases are available from the corresponding author upon reasonable request.

Registration of Studies and Data Management

The retrieved search results were exported to the Rayyan platform, a specialised web-based application designed to facilitate study selection, reference management, and collaborative screening amongst the research team. This platform was utilised strictly to remove duplicate records and facilitate blinded, independent title and abstract screening by human reviewers (DRP and MAG). The platform's labelling tools were used manually to categorise reasons for inclusion or exclusion according to the eligibility criteria.

Selection Process and Data Extraction

Study selection was performed in two consecutive phases. In the first phase, two independent reviewers (DRP and MAG), blinded to each other's decisions, screened the titles and abstracts of the identified records. Studies that met the initial screening criteria were retrieved in full text and evaluated during the second phase by the same reviewers, who rigorously applied the predefined inclusion and exclusion criteria. Any disagreements between reviewers were resolved through consensus or, when necessary, by consulting a third reviewer (MBP). The entire selection process workflow was documented in accordance with the PRISMA flow diagram. Data extraction from the eligible studies was conducted by these reviewers using a standardised data collection form. The following variables were extracted: first author, year of publication, study design, sample size, age and sex distribution of the participants, prevalence of MIH (along with its corresponding 95% confidence intervals [CIs]), and the diagnostic criteria utilised for classification. In instances of incomplete or ambiguous data, attempts were made to contact the corresponding authors of the primary studies to obtain clarification or additional information.

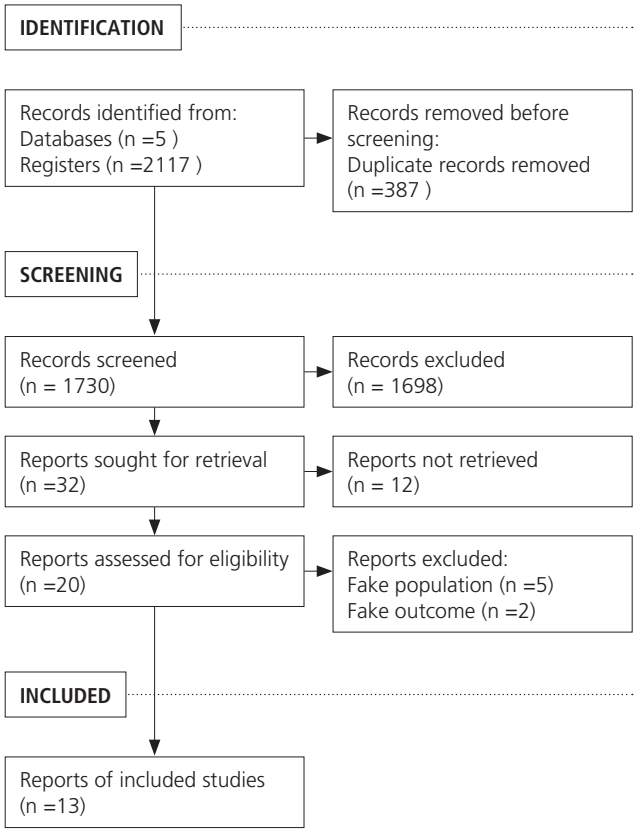


FIG. 1 PRISMA 2020 flow diagram of the literature search and study selection process for the systematic review and meta-analysis.

Assessment of Methodological Quality

To assess the methodological quality of the included studies, the Joanna Briggs Institute (JBI) Critical Appraisal Checklist for Prevalence Studies was used, which assesses aspects such as representativeness of the sample, sample size, data collection methods and statistical analysis. This tool has nine assessment items, each of which can be assessed as: Yes, No, Unclear and Not applicable. Two reviewers (DRP and MAG) independently assessed the quality of each study, and any disagreements were resolved by consensus or with the involvement of a third reviewer.

Synthesis Methods

Study-specific and pooled prevalences of MIH were estimated on the logit scale, with exact Clopper-Pearson intervals for the individual samples. A random-effects model was used throughout, fitted as a random-intercept logistic regression with the between-study variance estimated by maximum likelihood, and no common-effect estimate was computed. Pooled prevalences were back-transformed to the prevalence scale and are reported with 95% confidence intervals (CI). Heterogeneity was summarised through 95% prediction intervals, with the I^2 statistic reported alongside. Prevalence was also estimated by study setting (school-based, population- or community-based, and clinical/dental), and the difference between settings was tested. Funnel-plot asymmetry and small-study effects were assessed visually and with Peters' regression test. Two univariable meta-regressions were fitted on the logit scale, on year of publication and on mean age, the latter defined as the midpoint of the youngest and oldest age in each sample. Coefficients were expressed as odds ratios (OR) per one-unit increase. These analyses were exploratory and were not corrected for multiple testing. Prevalence by sex was analysed in the samples reporting counts for girls and boys separately. Logit-transformed prevalences were modelled with a multivariate random-effects model including sex, setting and their interaction, with sex nested within study, fitted by restricted maximum likelihood. Predicted prevalences with their confidence and prediction intervals were back-transformed to the prevalence scale. All analyses were performed in R version 4.6.0 with the meta and metafor packages.

RESULTS

Study Selection

The study selection process is summarised in Figure 1. After removing duplicates and screening titles, abstracts, and full texts according to the predefined eligibility criteria, 13 studies comprising 15 independent samples were included in the systematic review and meta-analysis.

Study Characteristics

The meta-analysis comprised 15 independent samples drawn from 13 cross-sectional studies published between 2006 and 2026, with a combined 6,978 children and adolescents (Table 1). Two studies each contributed two non-overlapping samples defined by age stratum [Cots et al., 2024, Maurenza Cuesta et al., 2018]. Sample sizes ranged from 92 to 840 participants (median, 489). The studies came from five Spanish Autonomous Communities, namely Catalonia (4 samples), Valencia (3), Madrid (2), Andalusia (2) and Asturias (2), together with

Study	Region	Setting	Sampling method	Age range	Sex distribution	n	Diagnostic criteria
[Ortega Luengo S et al. 2024]	Madrid	Clinical/dental	Consecutive	8-16	Female: 258 (52.8%) Male: 231 (47.2%)	489	Ghanim et al. 2015
[Hernandez M et al. 2018 (a) and (b)]	Catalonia	Population-based/community	Cluster	6-14.9	Female: 330 (46.8%) Male: 375 (53.2%)	705	EAPD / Weerheijm et al. 2003
[Garcia-Margarit M et al. 2014]	Valencia	School-based	Cluster	8-9	Female: 412 (49.0%) Male: 428 (51.0%)	840	EAPD / Weerheijm et al. 2003
[Negre-Barber A et al. 2016]	Valencia	Population-based/community	Consecutive	8-9	Female: 202 (48.8%) Male: 212 (51.2%)	414	EAPD / Weerheijm et al. 2003
[Gavara Navarro MJ et al. 2017]	Valencia	School-based	Convenience	8-12	Female: 338 (53.7%) Male: 292 (46.3%)	630	EAPD / Weerheijm et al. 2003
[Maurenza Cuesta U (a) et al. 2018]	Asturias	Population-based/community	Census	7-8	Female: 56 (47.1%) Male: 63 (52.9%)	119	EAPD / Weerheijm et al. 2003
[Maurenza Cuesta U (b) et al. 2018]	Asturias	Population-based/community	Census	13-14	Female: 56 (60.9%) Male: 36 (39.1%)	92	EAPD / Weerheijm et al. 2003
[Cots E (a) et al. 2024]	Catalonia	School-based	Convenience	12	Female: 354 (48.8%) Male: 371 (51.2%)	725	EAPD / Weerheijm et al. 2003
[Cots E (b) et al. 2024]	Catalonia	School-based	Convenience	6-12	Female: 268 (46.4%) Male: 309 (53.6%)	577	EAPD / Weerheijm et al. 2003
[Bech Barcaz L et al. 2025]	Andalusia	School-based	Simple random	6-7	Female: 106 (46.3%) Male: 123 (53.7%)	229	Ghanim et al. 2015
[Martinez Gomez T et al. 2011]	Catalonia	Clinical/dental	Consecutive	6-14	Female: 246 (48.7%) Male: 259 (51.3%)	505	EAPD / Weerheijm et al. 2003
[Comes Martínez A et al. 2007]	Madrid	Population-based/community	Simple random	9-12	Female: 111 (57.5%) Male: 82 (42.5%)	193	EAPD / Weerheijm et al. 2003
[Jimenez Moreno E et al. 2015]	Andalusia	School-based	Census	6-7	Female: 199 (47.0%) Male: 224 (53.0%)	423	EAPD / Weerheijm et al. 2003
[Bravo Perez M et al. 2016]	National	School-based	Cluster	12	Female: 308 (52.3%) Male: 281 (47.7%)	589	EAPD / Weerheijm et al. 2003
[Bravo Perez M et al. 2020]	National	School-based	Cluster	12	Female: 220 (49.1%) Male: 228 (50.9%)	448	EAPD / Weerheijm et al. 2003

TAB. 1 Characteristics of the included studies

Study	Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Q9
Ortega Luengo S et al. 2024	?	-	+	+	-	+	+	+	?
Hernandez M et al. 2018	+	?	+	-	+	+	+	-	?
Garcia-Margarit M et al. 2014	+	+	+	+	+	+	+	?	?
Negre-Barber A et al. 2016	+	?	+	+	+	+	+	+	?
Gavara Navarro MJ et al. 2017	?	-	+	+	+	+	+	-	?
Maurenza Cuesta U (a) et al. 2018	+	+	?	+	-	+	-	+	-
Maurenza Cuesta U (b) et al. 2018	+	+	?	+	-	+	-	+	-
Cots E (a) et al. 2024	?	-	?	+	+	+	-	?	?
Cots E (b) et al. 2024	?	-	?	+	+	+	-	?	?
Bech Barcaz L et al. 2025	+	+	+	+	+	+	-	?	?
Martinez Gomez T et al. 2011	-	-	?	+	?	?	?	?	?
Comes Martínez A et al. 2007	+	+	+	+	+	-	-	+	?
Jimenez Moreno E et al. 2015	+	+	+	+	?	+	+	?	?
Bravo Perez M et al. 2016	+	+	+	+	+	+	?	+	+
Bravo Perez M et al. 2020	+	+	+	+	+	+	?	+	+

FIG. 2 Risk-of-bias assessment using the JBI Critical Appraisal Checklist for Prevalence Studies. Q1: Was the sample frame appropriate to address the target population? Q2: Were study participants sampled in an appropriate way? Q3: Was the sample size adequate? Q4: Were the study subjects and setting described in detail? Q5: Was data analysis conducted with sufficient coverage of the identified sample? Q6: Were valid methods used for the identification of the condition? Q7: Was the condition measured in a standard, reliable way for all participants? Q8: Was there appropriate statistical analysis? Q9: Was the response rate adequate, and if not, was the low response rate managed appropriately?

Judgement

+	Yes	?	Unclear	-	No

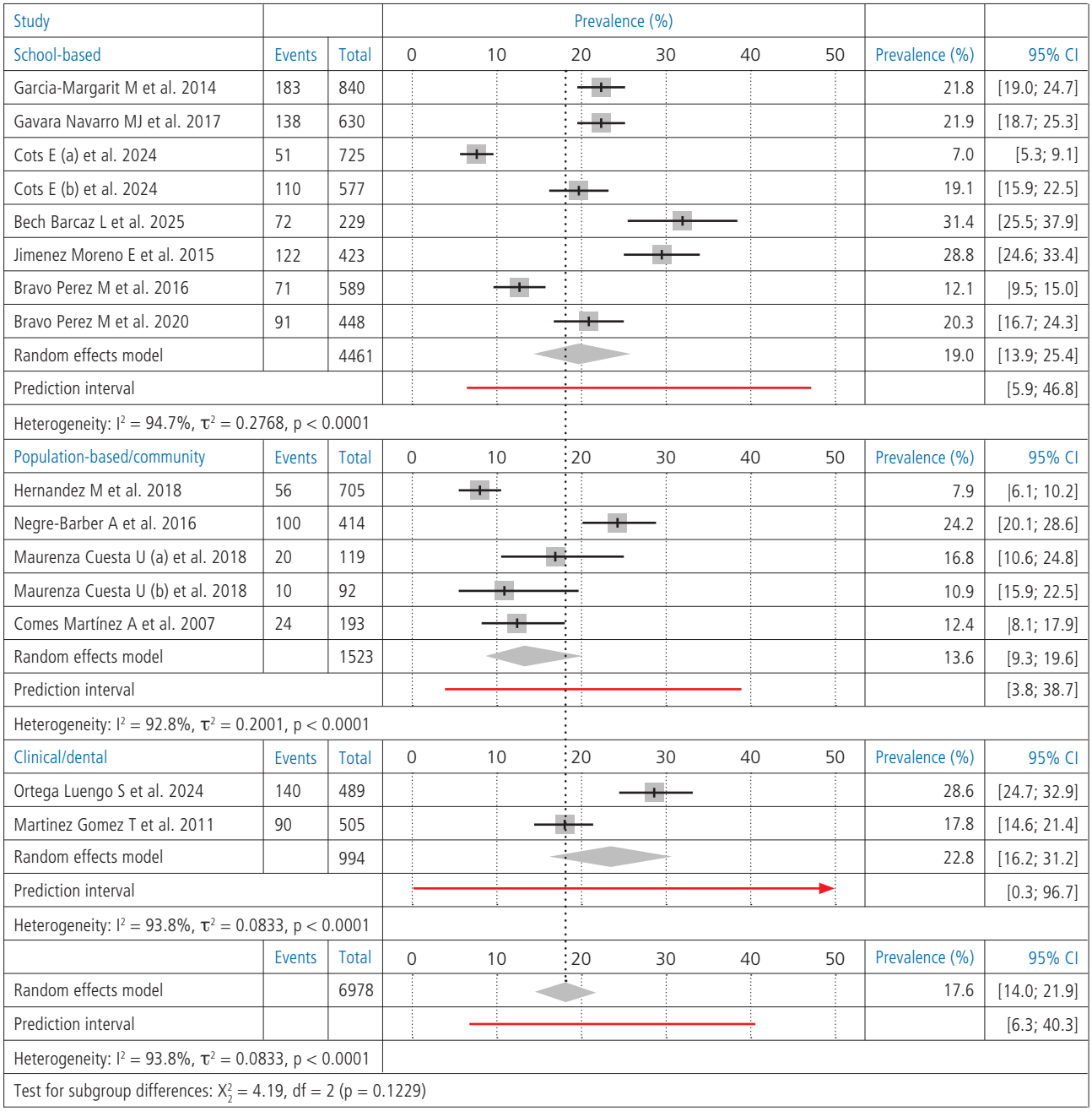


FIG. 3 Forest plot of MIH prevalence by sample, with random-effects pooled estimates overall and by setting

two nationally representative samples. Participants' ages ranged from 6 to 16 years, and three samples were restricted to 12-year-olds. The sex distribution was approximately balanced, the proportion of girls ranging from 46.3% to 60.9% across samples. By setting, 8 samples were school-based, 5 population- or community-based and 2 clinical/dental. Sampling strategies comprised cluster (4 samples), consecutive (3), convenience (3), census (3) and simple random (2) selection. MIH was ascertained using the European Academy of Paediatric Dentistry (EAPD) criteria [Lygidakis et al., 2022] in 13 samples and the Ghanim criteria [Ghanim et al., 2015] in the remaining 2.

Risk of Bias

Overall, the included samples were at low to moderate risk of bias (Figure 2). Most described their subjects and setting in detail (item 4, met in 14 of 15 samples) and relied on valid methods to identify MIH (item 6, 13 of 15), and roughly two-thirds used an appropriate sampling frame (item 1) and an adequate sample size (item 3, 10 of 15 each); the two nationally representative samples [Bravo et al., 2016, Bravo et al., 2020] were the most robust, satisfying 8 of the 9 items, whilst the study of Martínez Gómez [Martínez Gómez et al., 2012] sat at the opposite end, meeting only one. The response rate and its handling (item 9) went unreported or unclear in 11 of

15 samples, and the standardised, reliable measurement of MIH (item 7) was secured in only 6. This last domain mirrored examiner calibration almost exactly, the 6 samples that documented inter-examiner agreement (Cohen's kappa 0.74–0.98) being precisely those judged to have measured the condition reliably, whereas the 6 that reported no calibration and the 3 that calibrated without quantifying agreement [Bravo et al., 2016, Bravo et al., 2020, Martínez Gómez et al., 2012] were rated "no" or "unclear", respectively; a further 5 samples fell short on appropriate participant sampling (item 2).

MIH Prevalence

A total of 1,278 children were classified as having MIH across the 15 samples. The observed prevalence varied widely between samples, from 7.0% (95% CI: 5.3–9.2; [Cots et al., 2024]) to 31.4% (95% CI: 25.5–37.9; [Bech Barcaz et al., 2025]). (Figure 3). Pooling the samples in a random-effects model gave an overall prevalence of 17.6% (95% CI 14.0–21.9). Consistent with this dispersion, between-sample heterogeneity was high (I^2 = 93.9%), and the 95% prediction interval ranged from 6.3% to 40.3%, so the prevalence anticipated in a further Spanish setting could plausibly lie anywhere across that span. The pooled estimate was robust in a leave-one-out analysis, ranging only between 16.8% and 18.8% when any single sample was omitted. Pooled estimates by setting were 19.0% (95% CI 13.9–25.4) in school-based samples (k=8), 13.6% (9.3–19.6) in population- or community-based samples (k=5) and 22.8% (16.2–31.2) in the two clinical/dental samples. The data provided little evidence of a difference between settings (test for subgroup differences Q = 4.19, df = 2, p = 0.123), and heterogeneity persisted within each group, the prediction interval reaching 5.9–46.8% for school-based and 3.8–38.7% for population- or community-based samples, whilst that for the clinical/dental subgroup (0.3–96.7%) was uninformative given only two samples. Peters' regression test gave no evidence of funnel-plot asymmetry or small-study effects (t = 0.24, df = 13, p = 0.815; Figure 4). Two univariable meta-regressions were fitted to explore this heterogeneity (Figure 5). Year of publication showed no clear association with prevalence (odds ratio 1.01 per year, 95% CI 0.96–1.07; QM = 0.23, p = 0.635; Figure 5 A). Mean age, by contrast, was inversely associated

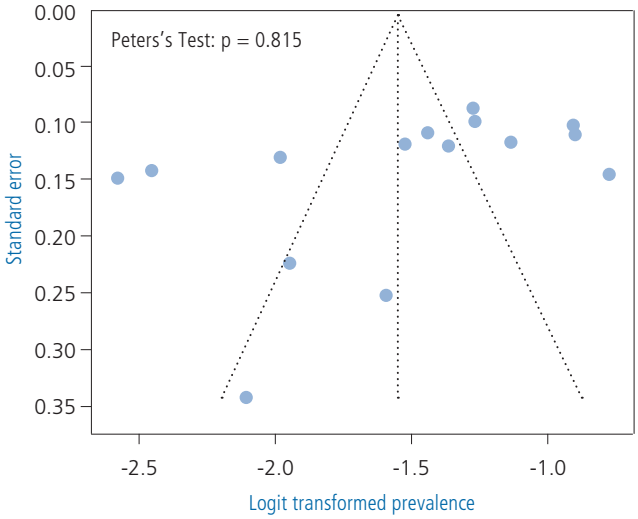


FIG. 4 Funnel plot of logit-transformed MIH prevalence against its standard error

with prevalence, each additional year corresponding to an odds ratio of 0.86 (95% CI 0.77–0.96; QM = 7.19, p = 0.007), the fitted line declining across the observed age range (Figure 5 B). Residual heterogeneity nonetheless remained high in both models (I^2 = 94.5% for year and 92.0% for age). Prevalence by sex was examined in the 12 samples reporting sex-specific counts (k = 5 school-based, 5 population- or community-based and 2 clinical/dental) using a multilevel model with sex, setting and their interaction (Figure 6). Model-based prevalences were similar in girls and boys within every setting, at 20.2% (95% CI 14.3–27.7) versus 21.4% (15.3–29.2) in school-based samples, 14.3% (9.6–20.9) versus 13.5% (9.0–19.9) in population- or community-based samples, and 25.3% (15.0–39.4) versus 20.3% (11.7–33.0) in clinical/dental samples. The corresponding prediction intervals were wide and largely overlapping between the sexes, approximately 9–42% in school-based, 5–31% in population- or community-based and 8–50% in clinical/dental samples, mirroring the persistent heterogeneity.

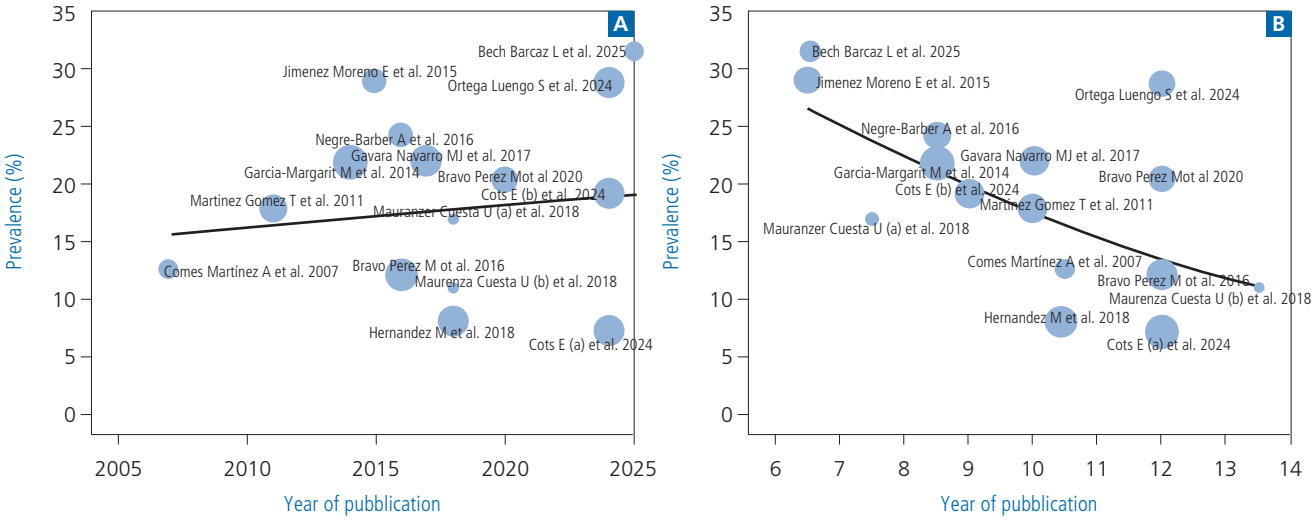


FIG. 5 Meta-regression of MIH prevalence on year of publication (A) and mean age (B). Bubble size is proportional to sample size; the line shows the fitted association

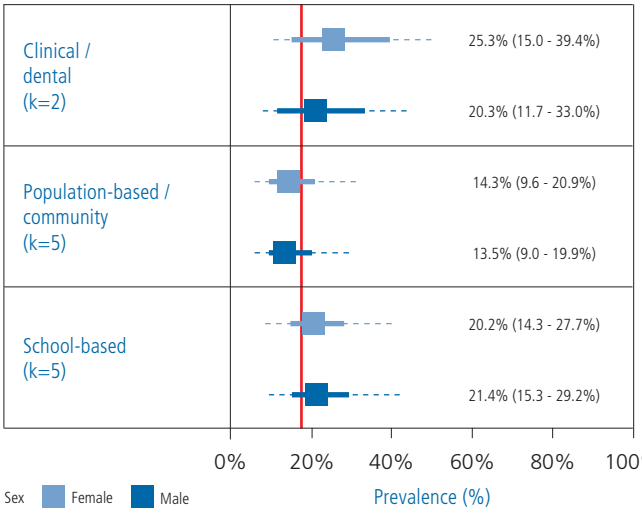


FIG. 6 MIH prevalence by sex and setting. Solid lines, 95% CI; dashed lines, 95% prediction interval; red line, overall pooled prevalence

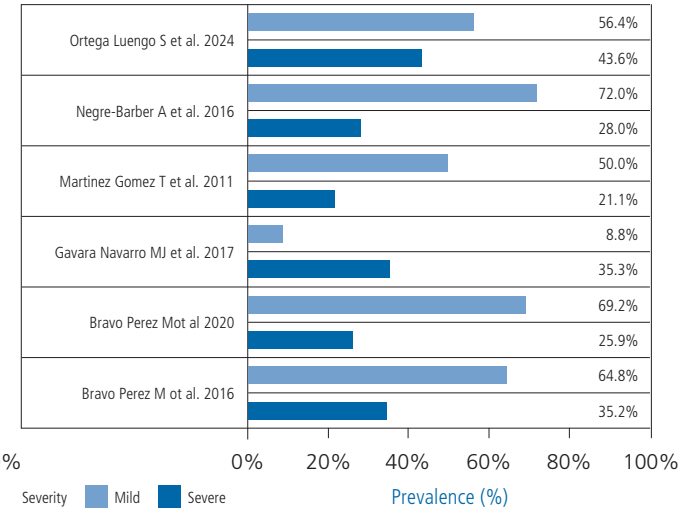


FIG. 7 Reported distribution of MIH severity (mild vs severe) among affected children, by study.

Neither the main effect of sex (boys versus girls, p = 0.474) nor the joint test of the sex, setting and interaction terms (QM = 7.30, df = 5, p = 0.199) indicated systematic differences; only the sex-by-clinical/dental interaction approached conventional thresholds (–0.36 on the logit scale, 95% CI –0.73 to 0.02, p = 0.061), driven by the lower male estimate in that two-sample subgroup.

MIH Severity

Six samples reported the distribution of severity amongst affected children (Figure 7). The reported proportion of mild forms ranged from 8.8% to 72.0% and that of severe forms from 21.1% to 43.6%. Mild involvement was the more frequent category in five of the six samples; the study of Gavara [Gavara Navarro, 2017] was the exception, reporting more severe (35.3%) than mild (8.8%) cases.

DISCUSSION

From an epidemiological standpoint, characterising the prevalence and severity of MIH in the paediatric population not only quantifies the true extent of this condition in our population but also provides an essential baseline that allows paediatric oral health services to anticipate the demand for complex treatments. Global distribution varies widely, and although epidemiology seeks to standardise studies using objective diagnostic criteria at the regional level, the same pattern holds true, as we have seen in our study as well as in previous comparative studies conducted in Spain where no meta-analysis was previously performed [Lopes et al., 2021, Peralvo-Álvarez et al., 2016].

Geographic Variation

Prevalence estimates cluster by region in a manner suggesting genuine geographic differences rather than measurement artefact. Barcelona province studies consistently reported low prevalence (7.94–7.95%) [Hernández et al., 2018a,b], whilst Madrid studies found high rates (28.63%) [Ortega-Luengo et al., 2024, Ortega-Luengo et al., 2025, Comes Martínez et al., 2007], and Valencia showed intermediate values (21.8–25.6%) [Negre-Barber et al., 2016, García Margarit et al., 2014, Gavara Navarro et al., 2017]. Within Madrid, socioeconomic disparities emerged: Parla, a municipality with lower per capita income, exhibited 39.2% prevalence compared to 21.7% in wealthier Alcobendas [Ortega-Luengo et al., 2024, Ortega-Luengo et al., 2025, Comes Martínez et al., 2007]. This socioeconomic gradient suggests environmental or systemic factors vary by region. The highest Spanish prevalence (32.8%) occurred in southwestern Andalusia, an area characterised by social disadvantage and high proportions of migrant populations [Bech Barcaz et al., 2025, Jiménez Moreno, 2015]. These geographic patterns could indicate that local environmental exposures, healthcare access, or population characteristics genuinely differ across Spanish regions rather than reflecting solely methodological variation.

Methodological Differences

Studies diverged in critical design elements that affect prevalence estimation. Population type systematically influenced findings: clinic-based samples yielded the highest pooled prevalence (22.8%; 95% CI: 16.2–31.2) [Ortega-Luengo et al., 2024, Martínez Gómez et al., 2012], school-based samples showed intermediate estimates (19.0%; 95% CI: 13.9–25.4) [Cots et al., 2024, García Margarit et al., 2014, Gavara Navarro, 2017], whilst population- or community-based surveys yielded the lowest pooled prevalence (13.6%; 95% CI: 9.3–19.6) [Maurenza Cuesta et al., 2018, Hernández et al., 2018a, Comes Martínez et al., 2007]. Population/community-based studies often utilise broad public registries or unselected health district screenings, minimising selection bias inherent to clinics and capturing non-seeking asymptomatic children. Furthermore, children attending dental clinics frequently present a higher burden of oral disease and receive more comprehensive clinical examinations, increasing the likelihood of detecting milder MIH lesions that might remain unnoticed in community-based screenings. In contrast, school-based surveys generally provide a more representative estimate of population prevalence but may underestimate the true burden of the condition because of logistical constraints, limited examination conditions, and the absence of complementary diagnostic tools. Consequently, differences in sampling frames should be considered when comparing prevalence estimates across studies, as they introduce an important source of methodological heterogeneity.

Age range critically affected estimates: studies of 6–7 year-olds found 32.8% [Bech Barcaz et al., 2025], those examining single age cohorts (8 or 9 years) reported 21.8–25.6% [García-Margarit et al., 2014, Gavara Navarro, 2017], whilst broader age ranges (6–14 years) yielded lower estimates (7.94–17.85%) [Hernández et al., 2018a,b]. This age effect likely reflects both the developmental timing of MIH detection and the progressive masking of lesions over time. Around 8 years of age, when all first permanent molars and most incisors have erupted, MIH can be assessed more accurately before extensive post-eruptive enamel breakdown or restorative treatment occurs. Conversely, in older children, hypomineralised enamel may have undergone post-eruptive fracture, been restored, extracted, or affected by caries, making retrospective identification of MIH more challenging and potentially leading to underestimation of its prevalence [Lygidakis et al., 2022, Inchingolo et al., 2023]. Moreover, the inclusion of younger children with incompletely erupted first permanent molars may also influence prevalence estimates, as partially erupted teeth can hinder adequate clinical assessment and result in missed diagnoses. These findings support current recommendations that epidemiological surveys should preferably evaluate children around 8 years of age, when eruption is sufficiently complete and lesions remain clinically identifiable, thereby maximising diagnostic accuracy and facilitating comparisons across studies [Weerheijm et al., 2003]. Diagnostic criteria standardisation remained incomplete despite the widespread adoption of EAPD recommendations. Several studies did not specify the diagnostic criteria applied (as we described in Table 1 previously in the text), limiting the reproducibility and comparability of their findings. Even amongst studies using the EAPD criteria, important methodological differences persisted regarding examiner training and calibration. Studies reporting linear-weighted kappa values between 0.74 and 0.94 demonstrated substantial to almost perfect inter-examiner agreement, supporting the reliability of their prevalence estimates [Ortega-Luengo et al., 2024, Ortega-Luengo et al., 2025]. In contrast, other investigations provided only limited information on calibration procedures [García Margarit et al., 2014], making it difficult to assess the consistency of lesion identification and raising the possibility of observer-related variability.

Furthermore, differences in examination protocols influenced case ascertainment. For instance, the use of fibre-optic transillumination in one study [Martínez Gómez et al., 2012], whilst aiding in lesion visualisation, cannot be considered a standard diagnostic criterion for MIH according to EAPD guidelines and may lead to misclassification of subtle developmental defects as MIH lesions. Conversely, variations in tooth cleaning, drying time, lighting conditions, and the distinction between mild MIH lesions and other developmental enamel defects may have contributed to inconsistent diagnostic thresholds across studies.

Collectively, these methodological inconsistencies likely account for part of the heterogeneity observed in MIH prevalence in Spain and underscore the need for greater adherence to standardised diagnostic protocols, including examiner calibration and detailed reporting of examination procedures, to improve the validity and comparability of future epidemiological research. Sample size and sampling method introduced additional variability. Studies ranged from 193 to 1,302 children [Garot et al., 2018, Gavara Navarro et al., 2017], with smaller studies showing wider confidence intervals [Maurenza Cuesta et al., 2018]. Random school-based sampling [Hernández et al., 2018a,b, García-Margarit et al., 2014] provided more representative estimates than convenience clinic samples [Martínez Gómez et al., 2012, Comes Martínez et al., 2007], though clinic-based studies better captured severe cases requiring treatment.

Temporal Trends

Limited evidence suggests that MIH prevalence may be increasing in Spain. Martínez et al. documented a striking birth cohort effect in Madrid, reporting a prevalence of 5.9% amongst children born in 1995 compared with 23.4% in those born in 1998 [Martínez Gómez et al., 2012]. Likewise, the study of Maurenza Cuesta observed a progressive increase in prevalence according to year of birth [Maurenza Cuesta et al., 2018]. Although these findings could indicate a genuine temporal trend, they should be interpreted cautiously. Both observations originate from a limited number of regional studies, and changes in diagnostic awareness, examiner experience, and the gradual implementation of standardised EAPD criteria over time may have contributed to the apparent increase in prevalence. In addition, improvements in clinician training and greater recognition of mild MIH phenotypes are likely to have enhanced case detection in more recent cohorts, potentially inflating temporal comparisons. Conversely, systematic reviews and international meta-analyses have generally reported relatively stable global prevalence estimates across different time periods [Lopes et al., 2021, Ammar et al., 2025], suggesting that any temporal increase observed in Spain may reflect regional environmental influences, methodological differences between studies, or changes in diagnostic practices rather than a true rise in disease incidence. Given the multifactorial aetiology of MIH, it is also plausible that temporal changes in prenatal, perinatal, and early childhood exposures (such as environmental pollutants, respiratory illnesses, antibiotic use, or other systemic factors) could have modified disease risk in specific populations [Lygidakis et al., 2022, Silva et al., 2016]. Nevertheless, the current evidence remains insufficient to establish a definitive temporal trend [Ammar et al., 2025]. Longitudinal surveillance using standardised diagnostic protocols and nationally representative samples will be necessary to determine whether MIH prevalence is genuinely increasing in Spain or whether the observed variation primarily reflects methodological improvements in disease detection [Weerheijm et al., 2003].

Severity Distribution and Diagnostic Implications

Across the studies reporting severity, mild MIH was the predominant presentation (up to 72% of affected children) [Maurenza Cuesta et al., 2018, Negre-Barber et al., 2016].

In non-clinical field screenings, mild opacities account for most cases because children with severe forms (post-eruptive breakdown, hypersensitivity) often seek early restorative treatment, which may lead to restored or extracted teeth being classified differently or excluded. Recognising this high proportion of mild MIH is clinically vital: whilst mild opacities do not require complex restorations, they require early non-invasive preventive care (fluoride varnishes, remineralisation, biomimetic toothpaste) to prevent PEB over time [Lygidakis et al., 2022, Hjertberg et al., 2025]. Although mild forms predominate numerically, the high overall prevalence of MIH (17.6%) implies that the subset of severe cases represents a substantial absolute clinical burden requiring intensive restorative management, whilst the larger mild subgroup requires dedicated secondary prevention to avoid future enamel breakdown.

Integrative Interpretation

The convergence of evidence suggests Spain experiences

genuinely high MIH prevalence compared to global estimates of 13–15% [Lopes et al., 2021, Ammar et al., 2025]. Studies employing rigorous methodology (EAPD criteria, examiner calibration, adequate sample sizes) consistently found prevalence exceeding 14% across multiple regions [Maurenza Cuesta et al., 2018, Ortega-Luengo et al., 2024, Ortega-Luengo et al., 2025, García-Margarit et al., 2014, Negre-Barber et al., 2016], with meta-analytic estimates confirming Spain amongst countries with highest rates [Ammar et al., 2025]. The 7.94% Barcelona estimates [Hernández et al., 2018a,b] likely represent genuine regional differences rather than methodological artefacts, as these studies used validated EAPD criteria and large samples. Within Spain, prevalence varies systematically: Barcelona province (approximately 8%) < Valencia region (approximately 22%) < Madrid (approximately 29%) < southwestern Andalusia (approximately 33%). This gradient correlates with socioeconomic indicators, suggesting environmental or systemic factors contribute to MIH aetiology. The association with lower household income [Ortega-Luengo et al., 2025], migrant status [Bech Barcaz et al., 2025, Comes Martínez et al., 2007], and conditions like atopic dermatitis and food allergies [Hernández et al., 2018b] supports a multifactorial origin involving early childhood environmental exposures.

Strengths and Limitations

This study presents several key strengths, including being the first meta-analysis to establish the pooled prevalence of MIH in Spain, adherence to PRISMA guidelines, protocol registration in PROSPERO, robust subgroup analyses by setting and sex, and rigorous quality appraisal using the JBI tool. However, certain limitations must be acknowledged. First, high statistical heterogeneity ($I^2 > 90\%$) was observed, driven by differences in diagnostic criteria application, examiner calibration, and age groups. Second, data were unavailable for several Spanish Autonomous Communities, limiting nationwide geographical representation. Finally, variations in reporting severity hindered meta-analytic pooling of severity outcomes across all samples.

CONCLUSIONS

For clinical and public health purposes, a reasonable Spanish prevalence estimate is 15-22%, with recognition that specific populations (low socioeconomic status, certain geographic areas) may experience rates exceeding 30%. The consistent finding of increased caries susceptibility in MIH-affected teeth and high treatment needs indicate this condition represents a significant paediatric oral health burden warranting preventive attention. Although the majority of affected children exhibit mild enamel opacities, the high overall prevalence (affecting approximately 1 in 6 children) translates into a significant public health burden. While mild cases demand secondary preventive strategies (e.g., remineralisation and monitoring), severe cases present substantial complex restorative needs, supporting the need for standardized national oral health policies. More epidemiological studies with standardized criteria are needed to continue generating useful scientific evidence on this growing public health problem.

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