Caries prevalence and molar incisor hypomineralisation (MIH) in children. Is there an association? A systematic review

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Abstract

Aim Molar incisor hypomeralisation (MIH) is a dental condition clinically characterised by the presence of morphological and qualitative enamel defects involving the occlusal and/or incisal third of one or more permanent molars or incisors. Its worldwide prevalence ranges between 2.4 and 40%. Several harmful conditions, such as genetic or medical problems during pregnancy, may act together and increase the risk of MIH. The main objective of this systematic review is to assess whether there is a correlation between MIH and dental caries in mixed or permanent dentition.

Methods An electronic search was performed on PubMed (Medline), Scopus and Cochrane Library for articles published from August 2022 to April 2023. Cohort, cross-sectional, retrospective and prospective studies were included. In vitro and animal studies, as well as clinical cases and systematic reviews, were excluded. Studies not differentiating between mixed and permanent dentition were excluded. The observed variables were DMFT (Decayed Missed Filled Teeth) score, DMFS (Decayed Missed Filled Surface) and DMF scores related to FPM (First Permanent Molar) and the clinical prevalence of MIH.

Results: After full assessment, 23 articles were selected and included in the qualitative synthesis. Observational cross-sectional studies were evaluated through the AXIS system, while the Newcastle-Ottawa scale was used for cohort studies. The main limitation of this systematic review is that, currently, no RCT on MIH and its correlation with caries have been published. The data source was limited to cohort and cross-sectional studies.

Conclusions: DMFT, DMFS and DMFT on FPM scores are significantly different between the group of patients with MIH and the control group. The available evidence supports a correlation between MIH lesions and caries. Caries indexes scores increase proportionally to the severity of MIH.

KEYWORDS Molar Incisor Hypomineralisation, Caries, Prevalence, Mixed Dentition, Permanent Dentition, Enamel defects

Introduction

MIH: definition, etiology and prevalence

Molar incisor hypomineralisation (MIH) is a clinical situation in which morphological and qualitative defects of the enamel are observed, localised near the occlusal surface of the permanent molars and the incisal surface of the upper and lower incisors [Alves dos Santos and Maia, 2012]. The term Molar Incisor Hypomineralisation, was first introduced by Weerheijm in 2001 [Alves Dos Santos and Maia, 2012; Weerheijm, 2001; Fragelli et al., 2015].

The worldwide prevalence of MIH varies between 2.4 and 40% [Fragelli et al., 2015; Lygidakis et al., 2010]; in Northern Europe the epidemiological indices report lower data, with a variable interval between 3,6 and 25% [Weerheijm, 2001]. From an etiological point of view, a direct connection between MIH and a given triggering cause has not yet been demonstrated. In recent literature, various studies put forward the hypothesis that there are factors or conditions that determine the increased risk of onset. These include genetic, environmental factors, medical problems during pregnancy, respiratory diseases, excessive exposure to dioxins during breastfeeding and alterations in calcium and phosphate metabolism [Weerheijm, 2003; Lygidakis et al., 2010].

Clinical features and classification of MIH

Molar incisor hypomineralisation is clinically characterised by areas of opacity of defined size, asymmetrical shape, variable colour and porous appearance [Weerheijm, 2003]. Enamel with MIH shows a noTable reduction in mineral quality and quantity, in hardness and in the modulus of elasticity [Elhennawy et al, 2020]. There are currently multiple classifications to indicate the different forms of MIH manifestation. Cabral et al. [2020] developed a MIH assessment system based on 10 codes in relation to the magnitude of the morphological defect and its severity. The first codes refer to opacity of white, cream, brown and are associated with a variation in the translucency of the enamel; codes from 3 to 6 indicate post-eruption fractures or cavity formation in the enamel or dentin with the presence of yellowish opacity; finally, the latest codes indicate more serious situations, such as atypical restorations with infiltrated margins or tooth extraction due to MIH. Mathu-Muju and Wright [Almuallem and Busuttil-Naudi, 2018] classify MIH into three severity levels: mild, when the areas of opacity are not localised

in areas of masticatory stress and caries and hypersensitivity are not found; moderate, when the opacities are localised on molars and incisors, there is the presence of fractures or post-eruption cavities on one or two surfaces without cusp involvement and atypical restorations and sensitivity are also observed; and severe, characterised by coronal fractures, caries and serious aesthetic alterations.

Criteria for identification and differential diagnosis

The criteria used to identify MIH as follows: the presence of a delimited area opacity greater than 1 mm, variable color ranging from white to cream, yellow, and brown, localised on at least one permanent molar with concomitant defects on the permanent incisors; presence of incongruous restorations, hypersensitivity and disintegration of the enam. Other indicators include the presence of incongruous restorations, hypersensitivity, and enamel disintegration [Lygidakis et al., 2010]. The differential diagnosis is performed with: fluorosis, associated with the use of fluoride; enamel hypoplasia, which is a quantitative defect characterised by a reduction in the thickness of the enamel; amelogenesis imperfecta, a genetic condition in which the enamel is hypoplastic, hypomaturate and hypomineralised; incipient caries lesions (white spots) and hypomineralisation secondary to trauma, usually occurring during the deciduous dentition [Almuallem and Busuttil-Naudi, 2018]. Dental caries is a multifactorial infectious disease of dental tissues generally caused by the interaction of various factors, such as bacteria, host susceptibility, nutrition and time [Gugnani et al., 2011].

PICO question of the systematic review

The objective of this systematic review can be summarised by the following PICO question (Population, Intervention, Comparison, Outcome): (P) patients with mixed or permanent dentition(I) diagnosed with MIH(C) and a control group without MIH (O) lead to a different prevalence of carious lesions.

To our best knowledge, only few studies have systematically reviewed the association between MIH and carious lesions. In recent years, a significant number of case-control and cohort studies have been published on this topic [Americano et al., 2017]. The present review aims to update the current knowledge on the topic, also based on what was recently published. Given the increasing prevalence of MIH, it is paramount to expand the evidence on this topic.

Materials and methods

The systematic review was performed in accordance with the statement of Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) [Moher et al., 2015]. The revision has been registered in the PROSPERO register with the code CRD42020205018.

Information sources

The systematic review was conducted between August 1, 2022 and February 1, 2023. A late update of the clinical research was done on April 2023. Primary sources were selected using search engines, such as Pubmed (MEDILINE), Scopus and Cochrane Library. The Boolean operators used are "AND" and "OR". No restriction for time or language was applied.

Search strategy

The MeSH search terms are: "Dental Enamel hypoplasia", "Dental Caries". The main free-text terms are: "MIH" and "Molar Incisor Hypomineralisation".

The following terms were combined with the previously mentioned Boolean operators to complete the search: (((((molar incisor hypomineralisation) OR (MIH)) OR (dental enamel hypoplasia)) AND (dental caries)) AND (tooth decay)).

Author and Year	Reason for exclusion from the systematic review
Halal et al. 2020. [14]	Patients with deciduous dentition and HSPM study.
Dantas-Netas et al. 2016. [15]	Study focused on the relationship between MIH and quality of life associated with oral health.
Gorbatova. 2019. [16]	Article available only in Russian.
Gambetta-Tessini et al. 2019. [17]	Simultaneously analyzed MIH and HSPM. No ≠
Cho et al. 2008. [18]	Retrospective study of medical records.
Muratbegovic et al. 2007. [19]	Article focusing on prevalence and etiology.
Sidhu et al. 2019. [20]	Simultaneously analyzed MIH and HSPM. No ≠
Gambetta-Tessina et al. 2018. [21]	Simultaneously analyzed MIH, General Enamel Defects and HSPM.
Ghanim et al. 2011. [22]	Focused on prevalence and clinical features. Caries prevalence not considered.
Ghanim et al. 2012. [23]	Focused on HSPM.
Ebel et al. 2018. [24]	Simultaneously analyzed MIH and HSPM. No ≠
Samuel et al. 2017. [25]	Incomplete data reported regarding MIH association and caries.
Owen et al. 2018. [26]	Focused on HSPM.

MIH: Incisor-molar hypomineralization; HSPM: Second temporal molar hypomineralization; ≠: distinctions.

TABLE 1 Summary of excluded articles

The search string obtained on Pubmed is reported: ("dental enamel hypoplasia"[MeSH Terms] OR ("dental"[All Fields] AND "enamel"[All Fields] AND "hypoplasia"[All Fields]) OR "dental enamel hypoplasia"[All Fields] OR ("molar"[All Fields] AND "incisor"[All Fields] AND "hypomineralization"[All Fields]) OR "molar incisor hypomineralization"[All Fields] OR "MIH"[All Fields] OR ("dental enamel hypoplasia"[MeSH Terms] OR ("dental"[All Fields] AND "enamel"[All Fields] AND "hypoplasia"[All Fields]) OR "dental enamel hypoplasia"[All Fields])) AND ("dental caries"[MeSH Terms] OR ("dental"[All Fields] AND "caries"[All Fields]) OR "dental caries"[All Fields]) AND ("dental caries"[MeSH Terms] OR ("dental"[All Fields] AND "caries"[All Fields]) OR "dental caries"[All Fields] OR ("tooth"[All Fields] AND "decay"[All Fields]) OR "tooth decay"[All Fields]).

The search string on Cochrane library was: (((((molar incisor hypomineralisation) OR (MIH)) OR (dental enamel hypoplasia)) AND (dental caries))).

Eligibity criteria

The inclusion and exclusion criteria were established according to the above reported PICO question. The included studies were case-control, cross-sectional or cohort studies both prospective or retrospective; published or in press; articles regarding patients in mixed or permanent dentition diagnosed with MIH in which dental caries prevalence was assessed.

Exclusion criteria: in vitro or animal studies, case reports, systematic reviews or meta-analyses; studies involving with patients in deciduous dentition; studies that do not discriminate between MIH and other qualitative and quantitative enamel

Author and year	Introduction X / 1 (Yes)	Methods x / 10 (Yes)	Results x / 4 (Yes) * x / 1 (No)	Discussion x / 2 (Yes)	Other (AE, Cfi) ** x / 1 (Yes) - x / 1 (No)	Risk of bias T: x / 20
Corral-Nuñez et al. 2016. [27]	1 Yes 1/1	9 Yes 1 No 9/10	3 Yes / 1 No 4/5	1 Yes 1 No 1/2	1Yes 1 No 2/2	T: 17/20
Groselj et al. 2013. [28]	1 Yes 1/1	9 Yes 1 No 9/10	4 Yes / 1 No 5/5	1 Yes 1 No 1/2	1 Yes 1 No 2/2	T: 18/20
Jeremias et al. 2013. [29]	1 Yes 1/1	10 Yes 10/10	4 Yes / 1 No 5/5	1 Yes 1 No 1/2	1 Yes 1 No 2/2	T: 19/20
Costa-Silva et al. 2010. [30]	1 Yes 1/1	10 Yes 10/10	3 Yes / 1 No 4/5	1 Yes 1 No 1/2	1 Yes 1 NR 1/2	T: 17/20
Garcia-Margarit et al. 2013. [31]	1 Yes 1/1	10 Yes 10/10	4 Yes / 1 No 5/5	1 Yes 1 No 1/2	1 Yes 1 No 2/2	T: 19/20
Wuollet et al. 2018. [32]	1 Yes 1/1	10 Yes 10/10	4 Yes / 1 No 5/5	1 Yes 1 No 1/2	1 Yes 1 No 2/2	T: 19/20
Krishnan et al. 2015. [33]	1 Yes 1/1	8 Yes 2 No 8/10	2 Yes / 1 NR 2/5	1 Yes 1 No 1/2	1 Yes 1 Nr 1/2	T: 12/20
Lopes Fatturi et al. 2020. [34]	1 Yes 1/1	10 Yes 10/10	3 Yes / 1 No 4/5	2 Yes 2/2	1 Yes 1 No 2/2	T: 19/20
Kosma et al. 2016. [35]	1 Yes 1/1	9 Yes 1 No 9/10	4 Yes / 1 No 5/5	2 Yes 2/2	1 Yes 1 NR 1/2	T: 18/20
Heitmüller et al. 2012 [36]	1 Yes 1/1	9 Yes 1 No 9/10	3 Yes / 1 No 4/5	2 Yes 2/2	1 Yes 1 No 2/2	T: 18/20
Bhaskar et al. 2014. [37]	1 Yes 1/1	8 Yes 2 No 8/10	3 Yes / 1 No 4/5	1 Yes 1 No 1/2	1 Yes 1 No 2/2	T: 16/20
Tourino et al. 2016. [38]	1 Yes 1/1	9 Yes 1 No 9/10	4 Yes / 1 No 5/5	1 Yes 1 No 1/2	1 Yes 1 NR 1/2	T: 17/20
Negre-Barber et al. 2018. [39]	1 Yes 1/1	10 Yes 10/10	4 Yes / 1 No 5/5	1 Yes 1 No 1/2	1 Yes 1 No 2/2	T: 19/20
Raposo et al. 2019. [40]	1 Yes 1/1	7 Yes 3 No 7/10	2 Yes / 1 No 3/5	2 Yes 2/2	1 Yes 1 No 2/2	T: 14/20
Kuhnisch et al. 2017. [41]	1 Yes 1/1	9 Yes 1 No 9/10	4 Yes / 1 No 5/5	2 Yes 2/2	1 Yes 1 No 2/2	T: 19/20
Ahmad et al. 2019. [42]	1 Yes 1/1	8 Yes 2 No 8/10	4 Yes / 1 No 5/5	1 Yes 1 No 1/2	1 Yes 1 NR 1/2	T: 16/20
Tadikonda et al. 2015. [43]	1 Yes 1/1	7 Yes 3 No 7/10	3 Yes / 1 No 4/5	1 Yes 1 No 1/2	1 Yes 1 NR 1/2	T: 14/20

AE: Ethical Approval; Cfi: Conflict of Interest, NR: Not Reported; T: total

** In the results section, question 13 considers the answer "No" to be valid; for this reason 1 point is awarded.*

*** In the "other" section, question 19, regarding any conflict of interest, considers the answer "No" to be valid; for this reason 1 point is awarded.*

TABLE 2 Quality assessment and determination of the risk of bias of cross-sectional studies.

studies that simultaneously analyse MIH and Second Primary Molar Hypomineralisation (HSPM) without distinction.

Data collection and extraction

Two operators (FAV, RA) independently performed the search and the screening process, applying the previously described inclusion and exclusion criteria. The results were compared and extracted; in case of discrepancies, a third senior author (DG) was consulted, and any disagreement was resolved by consensus. The following data were extracted, exported to an Excel datasheet (Microsoft Office for Mac 2011 package) and organised according to the Cochrane Consumers and Communication Review Group's data extraction template: a) author; b) year of publication; c) study type; d) country; e) sample size; f) age; g) gender; e) dental stage; f) prevalence of MIH (percentage); g) index used for caries assessment; h) prevalence of caries and/or restorations; i) summary of the results; l) conclusions.

Quality assessment

The qualitative evaluation of the selected articles was carried out using certain indices depending on the type of study.

For cohort studies and case-control studies, the Newcastle-Ottawa Scale (NOS) [Wells et al., 2011] was used, while the AXIS system was required for transversal or cross-sectional studies [Ma et al., 2020].

The NOS is a widely used evaluation tool; it consists of 9 points and analyses the selection of the study sample, the comparability with the control group and the research results. Based on congruity with the NOS criteria, a study can be rated as good, fair, poor [Wells et al.,2011].

The AXIS method, introduced in 2016, is a critical evaluation tool that analyses study design, the risk of bias and the quality of the reported results; it consists of 20 points and is indicated for transversal or cross-sectional studies [Ma et al., 2020; Downes et al., 2016]. The AXIS system [Downes et al., 2016] consists of 5 sections: introduction (1 point), methods (10 points), results (5 points), discussion (2 points) and other (2 points).

The introduction evaluates the transparency of the research objectives; in the methods part, the research design, the statistical analysis strategy and the selected sample are observed; in the

Author and year	Type of study	Selection x / 4	Comparability x / 2	Exposure x / 3	Outcomes / Results x / 3	Item quality x / 9	Risk of bias
Costa Silva et al. 2017. [44]	Retrospective Cohort	*** 3/4	* 1/2	X	** 2/3	6/9	Low
Grossi et al. 2017. [45]	Case-Control	*** 3/4	* 1/2	* 1/3	X	5/9	Medium
Llena et al. 2018. [46]	Cohort	*** 3/4	* 1/2	X	** 2/3	6/9	Low
Americano et al. 2016. [47]	Case-Control	**** 4/4	* 1/2	* 1/3	X	6/9	Low
Ulusoy et al. 2016. [48]	Case- Control	*** 3/4	* 1/2	* 1/3	X	5/9	Medium
Llena et al. 2020. [49]	Retrospective Cohort	*** 3/4	* 1/2	X	*** 3/3	7/9	Low

X: parameter not included in the NOS.

TABLE 3 Quality assessment and determination of the risk of bias in cohort and case-control studies using NOS

results, the quality and reliability of the latter are examined; in the discussion, attention is focused on the limitations of the study and on the justification of the conclusions; in the other section, the declaration of conflicts of interest by the authors and the approval of the ethics committee are taken into consideration [Ma et al., 2020; Downes et al., 2016].

The greater the sum of the various points is (maximum T = 20), the better is the quality of the article.

The Newcastle Ottawa Scale (NOS) comes in two different formats, depending on whether it is a cohort study or a case-control. Three aspects are evaluated in the cohort studies: the selection of the research sample, the comparability and the results, also depending on the follow-up established by the authors. In the control case, the structure is similar, with the only difference that the analysis of the results is replaced by the item "exposure" [Wells et al., 2011].

In both cases, the result is determined by the sum of the stars (maximum 9) corresponding to each point on the evaluation scale. The higher is the final score, the lower is the risk of bias. Table 3 shows the evaluation of the selected articles. It is observed that the results varies between 5 — associated with a moderate risk of bias — and 7, which indicates a lower risk of bias and higher quality of the article.

Results

Search and selection

Using the MeSH and non-MeSH terms and applying the search strategy described above, a total of 751 articles were selected through Pubmed (Medline) and Cochrane Library. After removal of duplicates, the first identification phase ended with a total of 497 items. During the screening phase, 316 articles were eliminated after reading the title, while 145 were excluded after reading the abstract. The inclusion and exclusion criteria were applied to a total of 36 full-text articles potentially relevant for the review. The methodological criteria for eligibility determined the definitive inclusion of 23 articles, which were subsequently subjected to quality assessment by using certain indices and from which the data were then be extracted. The flow chart of the screening process according to the PRISMA statement is shown in Graphic 1.

Excluded items and related reason

Application of the criteria established for this review study yielded to the exclusion of 13 articles. The excluded articles and the reason that led to their exclusion are shown in Table 1.

Evaluation of the quality of the items included

The tools used for the qualitative assessment of the selected studies are the following: AXIS for cross-sectional or transversal studies (Table 2), NOS for cohort and case-control studies (Table 3). The AXIS system was applied to 17 articles, while NOS was applied to the remaining 6. A total of 23 articles moved to the qualitative evaluation.

Regarding the cross-sectional studies, the qualitative assessment of the articles brought to light different and variable results. Six articles received a score of 19/20 [Jeremias et al., 2019; Garcia-Margarit et al., 2014; Wuollet et al., 2018; Krishnan et al., 2015; Fatturi et al., 2020; Negre-Barber et al., 2018; Kühnisch et al., 2018], three received 18/20 [Grošelj and Jan, 2013; Kosma et al., 2016; Heitmüller et al., 2013], three a total of 17/20 [Corral-Núñez et al., 2016; da Costa-Silva et al., 2010; Tourino et al., 2016]; basically, the obtained results demonstrate a high validity of the scientific papers and a reduced risk of bias. Two papers had a score of 16/20 [Bhaskar and Hedge, 2014; Ahmad et al., 2019] and two achieved a score of 14/20 [Raposo et al., 2019; Tadikonda et al., 2015], demonstrating an intermediate risk of bias. Only one article has a greater association with potential bias [Krishnan et al., 2015]. Regarding the NOS scale, 4 articles demonstrated a reduced risk of bias, classified with the term low [da Costa Silva et al., 2017; Llena and Calabuig, 2018; Llena et al., 2020]. The remaining two articles, having obtained a lower numerical score, are associated with a moderate risk of bias [Grossi et al., 2017; Ulusoy et al., 2016]. Therefore, no cohort or case-control articles that had a high risk of bias were included in the systematic review.

Search results

The results are shown in Table 4. Variables considered for data extraction are: authors and year, the country in which the study was carried out, sample size, age and gender of the participants, prevalence of MIH, the parameters used for evaluation and the conclusion reported.

Interpretation of the results

The results obtained show conformity in the data collected. The articles included in the systematic review are 23. Of these, 17 are cross-sectional (74%), 3 case-control (13%) and 3 cohort studies (13%). The time span covered by the research is

approximately 10 years, with the oldest article dating back to 2010 [da Costa-Silva et al., 2010] and the most current one to 2020 [Llena et al., 2020]. From a geographical and epidemiological point of view, the association between caries and MIH has been most studied and analysed in South America; 8 articles are from Brazil (35%) and 1 from Chile (4.16%). In Europe, 1 article is from Slovenia (4.16%), 1 from Finland (4.16%), 4 from Spain (18%), 1 from Turkey (4.16%), 1 from Greece (4.16%) and 2 from Germany (9%); in addition, 1 article was from the UAE (4.16%) and 3 from India (13.04%).

Currently, according to the criteria established in the research, there are no studies carried out in North America, Africa and Oceania. The number of participants included in the studies vary between 4,989 [Krishnan et al., 2015] and 142 [Ahmad et al., 2019], with an overall average of 899 subjects analysed. The age range extends from 5/6 years, with a follow-up of 2 years [da Costa Silva et al., 2017] up to 15 years [Tadikonda et al., 2015]; the average age of the participants is 9.4 years and from a dental standpoint corresponds to the mixed dentition phase.

In 3 articles, no data regarding the gender of the participants were reported [Raposo et al., 2019; Tadikonda et al., 2015; da Costa Silva et al., 2017]. In the remaining 20, equilibrium is observed between the research samples, the general average being 47% for males (9 173/19 548) and 53% for females (10 375/19 548). The prevalence of MIH is between 36.5% [Heitmüller et al., 2013] and 7.3% [Krishnan et al., 2015]. In 3 articles the authors did not report any data on this. The mean prevalence of MIH in the mixed and permanent dentition is approximately 18.5%. The main parameter used to analyse the incidence and correlation of caries with a particular study group is the Decayed Missed Filled Teeth (DMFT) index, with its sub-indeces, such as DMF-S, applied to the dental surfaces (Surfaces) and the DMF -FPM, when the interest is focused solely on the first permanent molars [Llena et al., 2020. The COPD is the Spanish language version of the DMFT [Corral-Núñez et al., 2016]. For the diagnosis, evaluation and classification of carious lesions, various methods have been used: ICDAS [Gugnani et al., 2011], World Health Organization caries index [World Health Organization; 1997], and the Caries Assessment Spectrum and Treatment [Gugnani et al., 2011; Frencken et al., 2011]. The guidelines of the European Association of Pediatric Dentistry (EADP) have been employed to clinically determine the presence of MIH [Lygidakis et al; 2010].

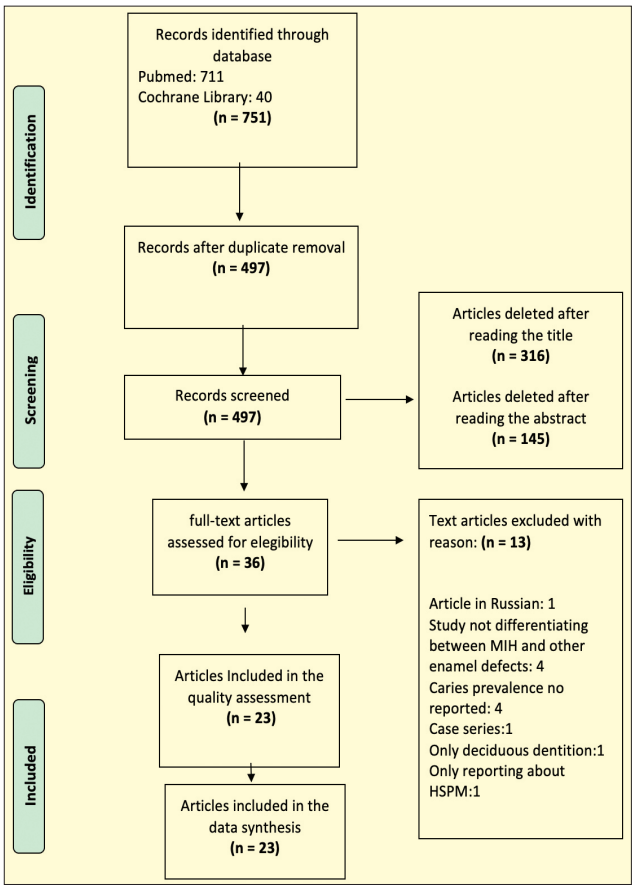

FIG. 1 Flowchart

Discussion

A direct association between carious lesion and higher DMFT index in patients with MIH is reported in 20 articles; just in one article [Heitmüller et al., 2013] this correlation was denied, while, in one study [Krishnan et al., 2015], no statistically significant data are reported. Corral-Nuñez et al. [2016] demonstrated that the mean value of the COPD index — that is, the Spanish language version of the DMFT — associated with MIH is 0.91, while in the control group it is 0.41; another statistically significant data is the item "fillings", mainly associated with the MIH group. In their epidemiological study, Grošelj and Jan [2013] obtained significant results regarding the DMF index related to tooth surface, permanent dentition and permanent first molars: in all three cases the values are closely associated with a clinical situation of MIH. Similar results are observed in the study by Jeremias et al. [2013], Costa-Silva et al. [2010], Grossi et al. [2017], Llena et al. [2018], Ulusoy et al. [2016] and Fernandes et al. [2021] where the DMFT indices in permanent dentition are higher in the MIH group. Garcia-Margarit et al. [2014] report that theDMFT and DMFS parameters, in addition to the mean number of carious teeth, are greater in the MIH group. Similar results are also observed in the study by Llena et al. [2020], with higher DMFS and DMFT indices in the MIH clinical condition group, as well as a correlation between MIH group and cavitated lesions and between cavitated lesions associated with non-cavitated lesions and permanent dentition and FPM.

In the article by Wuollet et al. [2018] and by Lopes Fatturi et al. [2020], both the DMFT and the DMF applied to FPM are more correlated to MIH. Also, in the study by Llena et al [2018], cavitated lesions and the combination of cavitated and non-cavitated lesions are greater in the MIH group. Bhaskar et al. [2014] and Americano et al. [2016] report similar findings regarding the MIH and caries association on FPM; in the case of Americano et al. [2016] a connection is observed between DMFS, DMFT and DMF on FPM> 0 in the MIH group; also, Tourino et al. [2016] and Ahmad et al. [2019], with statistically significant results, demonstrate the association between MIH and caries in permanent dentition. Tadikonda et al. [2015] reports the relationship between MIH and the average number of decayed dental elements, without however considering missing or filled teeth.

Vanhée et al. [2022], through their epidemiological study, demonstrated that the Decayed, Missing and Filled Teeth index (DMFT index) of MIH patients was significantly higher than non-MIH patients ($p < 0.001$), mainly due to more restored teeth and there was no correlation with dental fear.

Krishnan et al. [2015] do not report statistically significant data in their research; Kosma et al. [2016] document both that the FPM associated with MIH have a higher index of decayed or

Author and year	Type of study	Country	Number of participants	AgeDentition	GenderM / F	MIH prevalence (%)	Parameter used	Conclusions reported
Corral-Nuñez et al. 2016. [27]	Cross-sectional	Chile	N = 851	6-12 yearsMixed	M: 338 (40%) F: 513 (60%)	12.7%N = 108	COPD	COPD and specifically the Fillings factor are associated with MIH.
Groselj et al. 2013. [28]	Cross-sectional	Slovenia	N = 478	6-11.5 yearsMixed	M: 266 (56%) F: 212 (44%)	21.9%N = 105	DMF-TDMF-FPM	MIH associated with DMF> 0 in DP and FPM
Jeremias et al. 2013. [29]	Cross-sectional	Brazil	N = 1157	6-12 yearsMixed	M: 536 (46.3%)F: 621 (53.7%)	12.3%N = 142	DMFT	In the MIH group DMFT> 0 associated with caries
Costa-Silva. 2010. [30]	Cross-sectional	Brazil	N = 918	6-12 yearsMixed	M: 410 (44%) F: 508 (56%)	19.8%N = 182	DMFT	MIH associated with> prevalence of caries
Garcia-Margarit et al. 2013. [31]	Cross-sectional	Spain	N = 840	8 yearsMixed	M: 428 (51%) F: 412 (49%)	21.8%N = 183	DMFTDMFS	Caries index> in the MIH group
Wuollet et al. 2018. [32]	Cross-sectional	Finland	N = 636	6-13 yearsMixed	M: 328 (51.7%)F: 307 (48.3%)	18.1%N = 115	DMFT	MIH increases the risk of tooth decay, especially in FPM
Krishnan et al. 2015. [33]	Cross-sectional	India	N = 4989	9-14 yearsMixed and Permanent	M: 2158 (43.3%)F: 2831 (56.7%)	7.3%N = 384	EAPD for MIH	No differences between MIH group and control group in terms of association with caries.
Lopes Fatturi et al. 2020.[34]	Cross-sectional	Brazil	N = 731	8 yearsMixed	M: 357 (48.8%)F: 374 (51.2%)	12%N = 88	DMFT	Caries risk with MIH 2.52 times> compared to the control group
Kosma et al. 2016. [35]	Cross-sectional	Greece	N = 2335	8 and 14 yearsMixed and Permanent	M: 1139 (48.7%)F: 1196 (51.2%)	21.3%N = 498	EAPD for MIHDMFS	DMFS and DMFS on PMF with MIH >no MIH, except moderate MIH in the 14-year-old group
Heitmüller et al. 2012. [36]	Cross-sectional	Germany	N = 693	10 yearsMixed	M: 334 (48.2%)F: 359 (51.8%)	36.5%N = 253	DMF	No correlation between MIH and caries in the study group
Bhaskar et al. 2014 [37]	Cross-sectional	India	N = 1173	8-13 yearsMixed	M: 637 (54%) F: 536 (46%)	9.46%N = 111	EAPD for MIH	MIH associated with> caries index in FPM compared to control group
Tourino et al. 2016. [38]	Cross-sectional	Brazil	N = 1181	8-9 yearsMixed	M: 582 (49.3 %%)F: 599 (50.7%	20.4%N = 241	DMFTWHO Caries Index (1997)	Caries prevalence is 2 times> in MIH group compared to the control group
Negre-Barber. 2018. [39]	Cross-sectional	Spain	N = 424	8-9 yearsMixed	M: 212 (51.2%)F: 202 (48.8%)	24.2%N = 100	DMFSICDAS II	Caries in severe form > prevalent than moderate MIH

Raposo et al. 2019. [40]	Cross-sectional	Brazil	N = 631	8 yearsMixed	M: NOF: NO	16%N = 102	NOAnalyse Caries in Dentin	Severe MIH correlated with dentin caries
Kühnisch et al. 2017. [41]	Cross-sectional	Germany	N = 1302	14 yearsPermanent	M: 651 (50%) F: 651 (50%)	17.2%N = 224	DMFTDMFSICDAS	MIH L / M and severe MIH are associated with > risk of caries and > an index of NCCL
Ahmad et al. 2019. [42]	Cross-sectional	United Arab Emirates	N = 779	7-9 yearsMixed	M: 264 (34%) F: 515 (66%)	7.57%N = 59	DMFT	DMFT> in patients with MIH compared to the control group
Tadikonda et al. 2015. [43]	Cross-sectional	India	N = 352	11-15 yearsMixed and Permanent	M: NOF: NO	27%N = 95	EAPD for MIHWHO Caries index (1997)	Caries presence with MIH is 1.43 > compared to the control group
Costa-Silva et al. 2017. [44]	Prospective Cohort	Brazil	N = 142	5-6 yearsMixedFollow up 2 Y	M: NOF: NO	16.19%N = 23	DMFS	Association between MIH and IPV.No direct correlation with caries (not proven).
Grossi et al. 2017. [45]	Case-Control	Brazil	N = 260C = 130C = 130	7-13 years Mixed and Permanent	M: 137 (53%) F: 123 (47%)	NCA	DMFTCAST (caries)	DMFT> associated with MIH group. Dentin caries associated with MIH
Llena et al. 2017. [46]	Cohort (5 Y follow up)	Spain	N = 206Follow up 5Y	10 yearsMixed	M: 106 (51.6%)F: 102 (48.4%)	N = 4622.3%	DMFTDMFT-M	DMFT associated with MIH, regarding C (cavitate) lesions; MIH-associated DMFT-M in C and NC lesions
Americano et al-2016. [47]	Case-Control	Brazil	N = 155Houses: 57Control: 98	11 yearsMixed	M: 88 (57%) F: 67 (43%)	N = 4025.8%	DMFT	DMFT> 0 associated with MIH.DMFT in FPM> 0 with MIH
Ulusoy et al. 2016. [48]	Case-Control	Turkey	N = 162Case: 81Control: 81	8-11 yearsMixed	M: 64 (40%) F: 98 (60%)	NCA	DMFT	MIH group has a> DMFT (regardless of age range). Unchanged GI and PI
Llena et al. 2020. [49]	Retrospective Cohort	Spain	N = 278Follow up 7Y	12 yearsMixed andPermanent	M: 138 (49.3%)F: 140 (50.7%)	NCA	DMFMDMFTICDAS	DMFT and DMFM> in the MIH group compared to the control group

MIH: Molar Incisor Hypomineralization; M: Male; F: Female; Y: Year; PD: Permanent Dentition; COPD: Cariados Obturados Perdidos Dientes; N: number; GI: Gengival Index; S: Severe; M: Moderate; Mi: Mild; PI: Plaque Index; CD: Caries in Dentin; BL: Baseline; NCA: Not Calculated; DMF: Decayed Missed Filled; FPM: First Permanent Molar; FT: Filled Teeth; DMFT: Decayed Missed Filled Teeth; DMFS: Decayed Missed Filled Surfaces; DHL: Demarcated Hypomineralised Lesions; C: Cavitated; NC: Not Cavitated; DMFM o DMF-M: Decayed Missed Filled in First Permanent Molar; DHL: Demarcated Hypomineralised Lesions; NCCL: No Cavitated Carious Lesion; ICDAS: International Caries Detection and Assessment System; CAST: Caries Assessment Spectrum and Treatment; EADP: European Association of Pediatric Dentistry; WHO: World Health Organization.

TABLE 4 Results of the selected articles.

filled teeth, and that the DMFT in the 8- and 14-year-old group is, as also reported by the previously cited authors, linked to MIH and its degree of severity. In the article by Heitmüller et al. [2013] there is no association between caries index and MIH; in the Negre-Barber et al. study [2018], there was no difference in the prevalence of caries between the MIH group and the control group; however, analysing the severity of MIH, significant differences in the risk of caries are observed between the severe and moderate forms and between the severe and the control group. Similar results are observed in the study by Raposo et al. [2019] where only severe MIH is associated with a drastic increase in dentin caries. The manifestation of caries in dentin is also reported by Grossi et al. [2017], in whose study MIH patients have a greater predisposition to dentin carious lesion formation than the control group. Kühnisch et al. [2018] report a correlation between patients with MIH and severe MIH with respect to DMFS, DMFST and NCCL. In the study by Costa-Silva et al. [2017]; a statistically significant association is observed between visible plaque index (IPV) and MIH but not with caries; the authors put forward the hypothesis that IPV may be a determining factor for the development of caries in this type of patient. The systematic review analyses whether there is a correlation between a group of patients with a specific clinical condition, such as MIH, and the prevalence of carious lesions. The study of the association between these two variables was structured starting from the PICO question.

The results (Table 4) show conformity between the studies currently present in the literature; only in the article by Heitmüller et al. [2013] no type of correlation between MIH and caries has been reported. Costa-Silva et al. [2017] does not report a direct link between the two elements under study, but advances the hypothesis that the visible plaque index, associated with MIH, may be an indicator of high risk of caries in the future.

The data collected are therefore in line with what was documented in the systematic review published by Americano et al. [2017], in which the risk of developing a carious lesion in permanent dentition in the group of patients with MIH was, in a variable range between 2.1 and 4.6, greater than a control group. Consequently, various authors report DMFT-DMFS and DMF values associated with FPM closely linked to a condition of hypomineralization in mixed and permanent dentition [Corral-Núñez et al., 2016; Grošelj and Jan, 2013; Jeremias et al., 2013; da Costa-Silva et al., 2010; da Costa-Silva et al., 2017; Grossi et al., 2017; Llena and Calabuig, 2018; Americano et al., 2016; Ulusoy et al., 2016; Llena et al., 2020].

Furthermore, MIH severity has been shown to be exponentially associated with a higher caries index [Tourino et al., 2016; Negre-Barber et al., 2018].

MIH is considered a relatively new clinical condition, having been described for the first time in 2001. Most of the studies carried out with the aim of investigating the relationship between MIH and caries date back only to the last decade (2010–2020).

Since the worldwide prevalence is between 2.4 and 40% [Weerheijm, 2003; Fragelli et al., 2015; Lygidakis et al., 2010], it is paramount that dentists have proper knowledge of the condition, in order to achieve a prompt diagnosis and set up a plan for both prevention and therapy, where needed, also in light of the fact that MIH is severely associated with a worsening of the quality of life [Dantas-Neta et al., 2016].

Furthermore, from a clinical and practical point of view, the management of teeth with moderate and severe MIH requires extensive and in-depth experience in the use of the materials currently available on the market, as the adhesion capacity of the material on a hypomineralised surface is reduced.

Deep knowledge of MIH is necessary in order to avoid lesions to the teeth. Prevention plays an essential role [Aiuto et al., 2020].

Limitations of the systematic review

The main limitation of this systematic review lies in the selection of scientific articles. Most of the studies in the literature are cross-sectional; in fewer numbers, there are cohort and case-control studies. Currently, no randomised clinical trials have been published. The scientific value of a cross-sectional, transversal or epidemiological study is clearly reduced. Future studies are desirable, given the importance and prevalence of this specific clinical condition.

Conclusion

DMFT, DMFS and DMF-FPM values are higher in the MIH group. The data obtained from different studies analyzed in this systematic review show a correlation between dental caries and MIH. The association between these two factors is proportional to the degree of MIH severity. Further scientific studies are needed in the future to provide more information on the treated topic.

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