Prevalence and Diagnosis of Molar-Incisor-Hypomineralisation (MIH): A systematic review

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Abstract

AIM: This was to review the literature published, to point out shortcomings and to suggest areas in need of improvement concerning the diagnosis and prevalence of MIH. **METHODS**: A broad search of the PubMed database was conducted. Relevant papers published in English were identified after a review of their titles, abstracts or full reading of the papers. Papers were selected if the number of children with at least one first permanent molar affected by demarcated opacities could be deciphered. Targeted publications were critically assessed by the author concerning examination criteria, selection and character of the study groups, examiners' calibration and result presentation. **RESULTS:** The initial search revealed 414 papers of which 24 met the inclusion criteria. A wide variation in defect prevalence (2.4 – 40.2 %) was reported. Cross comparison of the results of the various studies were difficult because of use of different indices and criteria, examination variability, methods of recording and different age groups. **CONCLUSIONS:** Further standardization of study design and methods is needed to make the results comparable.

Introduction

Since the late 1970s, first permanent molars (FPM) with creamy-white to yellow-brown enamel opacities, in severe cases in combination with disintegration, have been observed frequently [Koch et al., 1987]. One to four molars, and often also the incisors, could be affected. Since first recognised, the condition has been puzzling and interpreted as a distinct phenomenon unlike other enamel disturbances e.g. amelogenesis imperfecta, fluorosis or chronological hypoplastic disturbances.

Diagnostic terms. Historically, a wide variety of terms and definitions have been used to describe various developmental defects of the enamel (DDE). Some are simply descriptive terms while others are linked to the causative agent e.g. fluoride. To remedy this confusion a FDI working group was established, and in 1982 the DDE index was published. This original index turned out to be too complicated to use in practice and a modified DDE index (mDDE) was presented in by FDI [1992].

Briefly, DDE are classified as demarcated opacities, diffuse opacities and hypoplasia. Opacity is defined as a qualitative defect of the enamel, whereas hypoplasia is defined as a quantitative defect of the enamel. Tooth surfaces are inspected visually, and defective areas tactilely explored with a probe. Natural or artificial light is used during examination, defects less than 1mm are not recorded, the teeth are not dried but large debris should be removed with help of a cotton roll. When the results are reported, the number of subjects with one or more teeth affected, the mean number of teeth per child affected by any defect, and by different types of defects are the standard data.

Koch et al. [1987] published a prevalence study in 1987 concerning malformed FPM. They did not use the DDE index but described the enamel defects in terms of colour and surface changes. The condition was named 'enamel hypomineralisation in FPMs'. Alaluusua and coworkers [1996a, b] published two studies concerning mineralisation defects in FPM with prevalence figures. They registered enamel defects in FPM and excluded hypoplasia, fluorosis, and defects related to major disturbances in general health. The degree of severity and size of the defects were also registered as: severe (loss of enamel with need for restoration, atypical restoration), moderate (loss of enamel), mild (colour change). Size was recorded as: large ($\geq$4.5 mm), moderate ($\approx$3.5mm), small ($\approx$2mm).

In 2001 three studies were published reporting the prevalence of FPM with enamel defects. Leppäniemi et al. [2001] used the 'Alaluusua criteria'. Weerheijm et al. [2001b] and Jälevik et al. [2001] used the mDDE index further adapted to be able to point out the phenomenon 'hypomineralized permanent first molars'. The authors of those papers met at the EAPD congress in Bergen 2000, and concluded that they described the same phenomenon and agreed on a definition and the nomenclature molar-incisor-hypomineralisation (MIH) [Weerheijm et al., 2001a].

The subsequent EAPD seminar in Athens 2003 strove to establish the judgment criteria for MIH in epidemiological studies. The mDDE index was considered to be too time consuming and not adequate for MIH studies. Post-eruptive breakdown (PEB) is prominent feature in MIH and the mDDE index does not clearly differentiate PEB from hypoplasia.

The EAPD seminar in 2003 agreed and published the following conditions [Weerheijm et al., 2003b]:

- Permanent first molars and incisors (12 index teeth) should be examined,
- Examination for MIH should be performed on wet teeth after cleaning,
- Eight years of age was the best time for examination,
- Each tooth should be recorded for:
  - absence or presence of demarcated opacities,
  - posteruptive enamel breakdown,
  - atypical restoration,
  - extraction due to MIH,
  - failure of eruption of a molar or incisor.

A number of prevalence studies of MIH have now been published from different parts of the world and a wide variation in defect prevalence has been reported. In spite of the EAPD criteria from 2003, comparison of the results of these various studies remains difficult because of the use of different indices and criteria, examination variability, methods of recording and different age groups. The aim of this paper is to review the literature concerning the diagnosis and prevalence of MIH to point out shortcomings and suggest areas in need of improvement.

Materials and Methods

A broad search of PubMed data was conducted using:

- developmental defects of the enamel (enamel developmental defects), prevalence AND developmental defects of the enamel defects (enamel developmental defects),
- molar-incisor-hypomineraliz(s)ation, prevalence AND molar-incisor-hypomineraliz(s)ation, prevalence AND MIH,
- non-fluoride hypomineraliz(s)ations in the first molars, cheese molars and hypomineraliz(s)ed permanent first molars as index terms.

To be considered for this review, the paper had to have been written in English and it must have been possible to decipher the number of children with at least one FPM affected by demarcated opacities. Of the 414 references initially found, 54 were targeted on the basis of their abstracts. After a full reading of the targeted papers, only 24 fulfilled the review criteria.

Results

All studies but one were cross sectional, observational studies. Cho et al. [2008] performed a retrospective study of records. According to the SIGN criteria, the quality of evidence of all studies was low (C-D) [Sign 50]. Only one third of the studies had study groups reflecting the background population (Table 1). Consequently, the majority of studies report the frequency of MIH in a specific group rather than as prevalence. In nearly half of the studies investigation for MIH

was the main purpose. However, it could also be a part of a general dental health survey or combined with an ordinary dental examination.

The sample sizes have varied considerably. Descriptions of the study groups were generally sparse or missing. Almost half of the study groups were mixed age groups, three of them [Koch et al., 1987; Dietrich et al., 2003; Kukleva et al., 2008] reported prevalence figures for each age group separately which showed a considerable variation between the groups (Fig1).

Figure 1. The prevalence of MIH in different age groups within three different studies:. a) Koch et al. 1987, b) Dietrich et al. 2003, c) Kukleva et al. 2008.
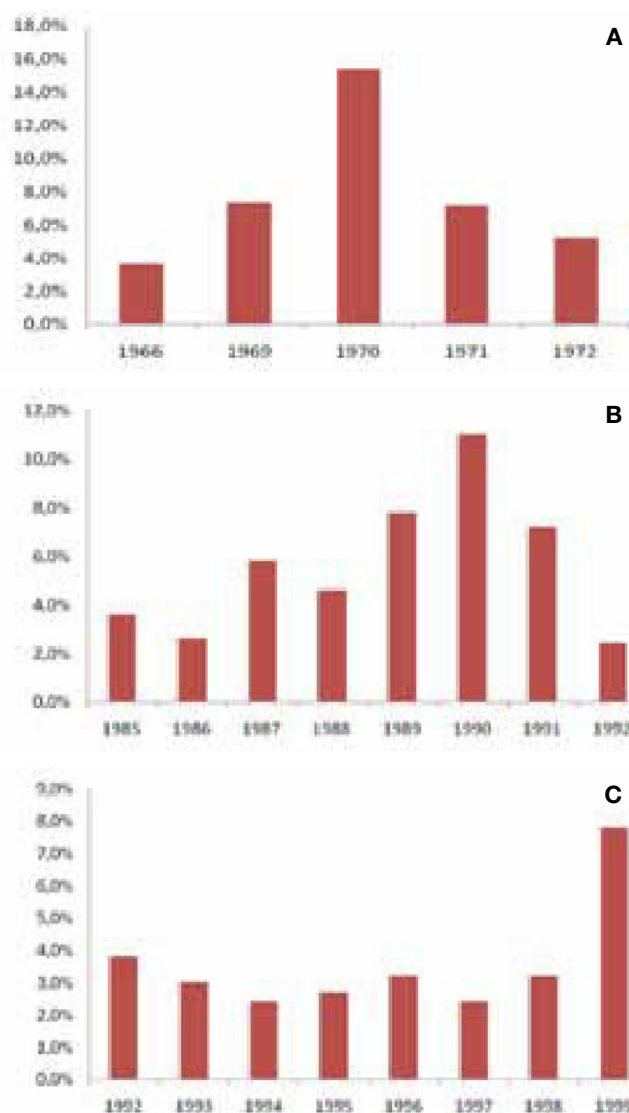
Table 1: Summary of epidemiological studies for molar-insicor hypomineralisation

Study	Country	Criteria	Study group	Population based?	Age	Sample size	Drop-outs	Calibration	Wet=W Dry=D	Size	Degrees of Severity	Frequency
Alaluusua et al. 1996a	Finland	Dental defects, fluorosis or major disturbances related to general health excluded.	Prospective cohort examined for dioxin in breast milk	No	6-7 yr	102	NR	NR	NR	≥ 2mm	3	17%
Alaluusua et al. 1996b	Finland	Alaluusua et al. 1996 a	Prospective cohort examined for dioxin in breast milk	No	12 yr	97	NR	NR	NR	≥ 2mm	3	25%
Arrow 2008	Australia	mDDE	Age cohort examined for MIH	Yes*	7 yr	511	R	Yes	D	NR	NR	22%
Balmer et al. 2005	UK	mDDE	Consecutive patients in orthodontic practice	No	8-16 yr	25	NR	Yes	NR	NR	NR	40%
	Australia					25						44%
Calderara et al. 2005	Italy	mDDE, MIH krit 2001	Age cohort examined for MIH	Yes	7-8 yr	227	R	Yes	W	≥ 2mm	3	13.7 %
Cho et al 2008	Hong Kong	EAPD 2003	Study of records	No	11-14 yr	2,635	NR	Yes	W	NR	NR	2.8%
Dietrich et al. 2003	Germany	mDDE	Patients at annual dental screening	No	8 age cohorts, 10-17 yr	2,408	R	Yes	NR	NR	3	2.4-11%, mean 5.6%
Fleita et al 2006	Libya	mDDE, MIH krit 2001	School cohorts	No	7-9yr	378	NR	Yes	W	≥ 2mm	3	2.9%
Jasulaityte et al. 2008	Lithuania	EAPD 2003	School cohort, randomly selected schools	Yes	6.5-8.5 yr	1,277	NR	Yes	W	NR	2	9.7%
Jasulaityte et al. 2007	Netherlands	MIH krit 2001	Age cohort insured by DNHIF	No	9 yr	442	R	Yes	D	NR	NR	14.3%
Jälevik et al. 2001	Sweden	mDDE	Age cohort	Yes	8 yr	519	R	Yes,	W	≥ 2mm	3	18.4%
Kemoli 2008	Kenya	Demarcatef opacities, posteruptive defects, extensive restoorations	School cohort, randomly selected schools	Yes	6-8 yr	3,591	NR	Yes	W	NR	1	13,70%
Koch et al.1987	Sweden	Colour and surface changes. AI, fluorosis or hypomin of known origin excluded.	Age cohorts	Yes	6 age cohorts, 8-13yr	2,252, 343-423 in the cohorts	NR	Yes	NR	≥1/3 of a tooth unit	3	3.6%-15.4%

Kukleva et al. 2008	Bulgaria	EAPD 2003	Randomly selected. Stratified age groups.	Yes	Eight age cohort, 7-14 yr	2970, 370 in each age cohort	NR	NR	W	NR	NR	2.4%-7.8%, mean 3.6%
Kuscu et al 2008	Turkey	EAPD 2003	Patients	No	7-9 yr	147	NR	Yes	W	NR	2	14.9%
Kuscu et al 2009	Turkey	EAPD 2003	Two school cohorts, Industrialized/non-industrialized area	No	7-10 yr	109 and 44	NR	Yes	W	NR	NR	9.1%; 9.2%
Leppäniemi et al. 2001	Finland	Alalausua et al 1996	Two school cohorts	No	7-13yr	488	NR	NR	NR	≥ 2mm	3	19.3%
Lygidakis et al. 2008	Greece	EAPD 2003	Consecutive patients in Community Paediatric Dental Center	No	5.5-12 yr	3518	NR	Yes	NR	Clearly visible	2	10.2%
Muratbegovic et al. 2007	Bosnia Herzegovina	EAPD 2003	Randomly selected Stratified school groups	Yes	12 yr	560	NR	NR	NR	≥ 2mm	NR	12.3%
Preusser et al. 2007	Germany	Koch et al. 1987	Schoolchildren	No	6-12yr	1002	NR	Yes	W	NR	3	5.9%
Soviero et al. 2009	Brazil	EAPD 2003	School cohort	No	7-13 yr	249	R	Yes	W	NR	2	40.2%
Weerheijm et al. 2001b	Netherlands	mDDE	Age cohort insured by DNHIF	No	11 yr	497	NR	NR	NR	NR	NR	9.7%
Wogelius et al. 2008	Denmark	MIH 2003	Age cohorts	Yes	6-8 yr	647	R	Yes	W	Clearly visible	2	37,50%
Zagdwon et al, 2002	UK	m DDE	School cohorts. Selected with account of ethnicity and socio-economy	No	7 yr	307	R	Yes	W	NR	NR	14.6 %

NR = Not reported, R = Reported, * particpation 45%

Prior to the publication of judgment criteria for MIH compiled by the EAPD meeting in 2003, the authors had to invent their own examination criteria as in Koch et al. [1987], Alaluusua et al. [1996a, b] and Leppäniemi et al. [2001] while Jälevik et al. [2001], Weerheijm et al. [2001] and Zagdwon et al. [2002] used the mDDE criteria further modified to the entity later on denominated MIH. The condition is thoroughly described in these papers and there is no doubt that MIH is concerned. After publication of the EAPD judgment criteria in 2003, some papers refer to the mDDE criteria, some to the EAPD criteria and some to both of them (Table1). Nevertheless, a recent study [Arrow, 2008], using the mDDE criteria, does not separate posteruptive enamel breakdown from hypoplasia.

Approximately half of the investigations were performed by 1-3 examiners and in most cases they were reported to have been calibrated. One third of the papers did not report the number of investigators. The calibration procedure varied from paper to paper; sometimes it was not described at all. The reported reproducibility was always reported as satisfactory. It was reported as Kappa values, percent of agreement or just as good.

The prerequisites for the examinations differed. Some were performed as ordinary examinations in the dental chair, while others were more or less primitive field surveys. Ten studies did not report if the teeth were examined dry or wet, one reported drying teeth with air syringe and the others examined wet teeth. One fourth did not report demarcated

opacities less than 2 mm, the remaining studies did not report any lower limit.

When reporting the prevalence of MIH, all papers refer to the portion of children having at least one FPM affected by MIH. Besides that, the ways in presenting results are probably as many as there are papers, such as tooth, jaw and/or gender distribution, severity and number of affected teeth.

The reported prevalence of MIH varies from 2.4% in Germany and Bulgaria [Dietrich et al., 2003; Kukleva et al., 2008] to 40.2% in Rio de Janeiro [Soveiro et al., 2009]. Actually, one study [Balmer et al., 2005] reported that 40% of children in Leeds and 44% of children in Sydney had demarcated opacities in at least one FPM. However, the study groups only consist of 25 children each, the age span was large and this study was not focusing on MIH. Therefore these results should be considered with caution.

Traditionally, there have been more studies from northern Europe, and MIH has appeared to be more common in those countries. However, lately studies have been published from other parts of the world. A very recent study from Brazil [Soviero et al., 2009] showed a prevalence of 40.2% and a study from Kenya 13.7% [Kemoli, 2008].

Discussion

Agreement on examination criteria and good, comparable studies is of utmost importance in trying to elucidate the phenomenon MIH. The criteria of the EAPD meeting in 2003 are referred to in most of the latter studies and seem to be well established among dentists with special interest in enamel disturbances. In spite of that, the methodology differs markedly from study to study making comparison difficult. Recruitment, representation, sample size and age of the examined children, wet or dry examination, minimum size of the defects, calibration of the examiners, and how to report the results are questions to be discussed.

Recruitment, representation of the study group. Only one third of the investigations were performed on whole age cohorts or randomly selected children in the target population. The other study groups could consist of patients in certain clinics, children insured by an insurance company or just schoolchildren from a selected school. How they were recruited was generally sparsely described. The ability of generalizing the results to the background population was never discussed. Information on socioeconomic and ethnic backgrounds factors was sparse and lacking discussion as to how those factors possibly could have affected the results. In those studies the frequency of MIH in a group of children is described rather than the prevalence. In all studies, descriptions of the children who dropped out were frequently missing.

Sample size and age. It is hard to give advice concerning the optimal sample size in cross sectional, observational studies. In view of the reported prevalence, the more the better

is probably a good answer. Regarding the reported variation between age groups [Koch et al., 1987; Dietrich et al., 2003; Kukleva et al., 2009] a recommendation is that the frequency of MIH should be reported for each age cohort separately. The 2003 EAPD meeting recommended 8 years of age as the best age for examination. At that age, in most children, all 4 FPM should be erupted, as will the majority of incisors. At a later age, there is a greater risk that tooth coloured fillings, especially, could be masking defects. An objection would be that all FPM and incisors are not erupted.

A conceivable study design would be to examine a group of children blind every second year from 8 until 14 or 16 years of age. Then a researcher could record and study variation over time. If new cohorts were started every second year it would also be possible to elucidate variation between age cohorts in the same population. A Dutch study has shown MIH on the second primary molars [Elfrink et al,. 2008]. A clinical observation is that the tips of canines quite frequently and also maybe second permanent molars and premolars could be affected. Therefore, all erupted teeth, not only FPM:s and incisors, ought to be examined for demarcated opacities.

Wet or dry teeth examination, minimum size of defects and calibration. When establishing the mDDE criteria, wet examination was proposed by the FDI Working group [1992]. Wet examination has also been used in many MIH studies. It is important that there should be congruenceon this criteria as a higher prevalence is reported from dry examinations compared to wet.

The essential decision as to whether a defect is present or not can be difficult. Trying to help ameliorate this problem it has been proposed not to record any defects smaller than 1 mm [Clarkson and O'Mullane, 1989]. Suckling et al. [1985] found that reproducibility of small opacities (less than 2mm) was low. Six of the reviewed studies have not reported opacities smaller than 2 mm. The others had no lower limit that leads to increased risks of mis-diagnosis of e.g. white spot lesions, white cuspal ridges or a patchy appearance of amelogenesis imperfecta or fluorosis.

Training and calibration of the examiners according to validated methods should be mandatory. An important task is to work out a well-defined method that future examiners could use. When performing vigorous studies more examiners would be needed. This emphasises the need for precise and validated examination criteria as well as well defined calibration procedures.

Reporting of the results. To facilitate comparisons of results from different prevalence studies it is advocated to reach a consensus for some basic results to be reported. Besides reporting how many children have at least one FPM affected it would be useful to report the number of index teeth affected in each child with MIH. Eruption stages influence this result; therefore it is useful to report the number affected

for a subgroup with all index teeth erupted [Wogelius et al., 2008, Lygidakis et al., 2008, Soviero et al., 2009].

The degree of disturbance seems to co-vary with the number of affected teeth [Jälevik et al., 2001, Jasulaityte et al., 2007], but not with the prevalence of MIH [Soviero et al,. 2009]. Therefore it is also important to report the severity of the defects in a comparable manner. Earlier studies have classified MIH into mild, moderate and severe defects [Alaluusua et al,. 1996 a,b; Jälevik et al,. 2001, Calderara et al,. 2005]. Lately, the moderate and severe groups have been combined into one group, named disintegrated or severe [Jasulaityte et al,. 2007; Lygidakis et al,. 2008]. This classification seems to involve reproducibility. To broaden the knowledge of the nature of MIH, it is of great importance to know to what extend other teeth than PFM and incisors are affected.

Conclusions

In order to reach the goal of comparable studies with good quality of evidence it is necessary to have well defined study groups representing the background population. Recruitment procedure as well as the rate of dropouts has to be very well described. Each age group ought to be reported on separately and considering the up to now reported prevalence each group ought to consist of at least 100 children. The age of 8 years, when all FPM are usually erupted is the best time for examination. An agreement on procedure and criteria of examination, as wet or dry teeth and minimum size of recorded defect, is needed. Preparing a well defined method for training and calibration of future examiners is of utmost importance. When reporting on MIH it is recommended to report the percentage of children with at least one FPM affected by MIH, the mean number of affected teeth, and the percentage of children with at least one FPM with severe defects. Information on other teeth affected than FPMs and incisors is also desirable.

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