

Definition and scoring system of molar incisor hypomineralization: A review

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Abstract

Objectives: A definition and classification system for molar incisor hypomineralization (MIH) was first suggested by the European Academy of Pediatric Dentistry (EAPD) in 2003. Since then, there has been growing interest in these mineralization defects due to esthetic and cariogenic susceptibility concerns. The aim of this review was to evaluate studies on MIH in an attempt to provide evidence for consistency and standardization of MIH definition and severity scoring reporting by clinicians and researchers.

Methods: Included were studies (research papers and reviews) focusing on MIH affected populations and containing a definition and scoring system. Only English language articles published in the period 2001 to 2015 were considered. Study selection and data extraction were performed by two independent investigators.

Results: More than half of the publications used the EAPD definition and fewer than half of the prevalence reports have either used the EAPD criteria or the developmental defects of enamel (DDE) index as their classification system. Others have either incorporated modifications or created their own scoring criteria. The lack of standardized definition and heterogeneity of scoring systems used might explain the considerable variability in prevalence figures.

Conclusion: In order to better define the diagnostic criteria and the treatment needs for those patients, a globally accepted standardized protocol for scoring system is required.

Introduction

Molar incisor hypomineralization (MIH) is the term used to describe a special pattern of enamel defects. The terminology was first used by Weerheijm *et al.* [1] describing developmental defects affecting first permanent molars and permanent incisors, ranging from distinct, isolated, white, yellowish, or brown-colored demarcated opacities to severe post eruptive structural breakdown. Shortly after MIH terminology was proposed, the European Academy of Paediatric Dentistry (EAPD) announced criteria specifically aiming at diagnosing and recording MIH [2,3].

Information available on the exact etiology of MIH is limited. A combination of factors that may affect the ameloblasts resulting in abnormal enamel formation has been suggested in most studies. Systemic or environmental insults during the maturation stages of enamel development as well as the possibility of genetic predisposition of ameloblasts to environmental stressors have been reported [4-6]. Some authors suggest that MIH may be an autosomal recessive condition or an unrecognized form of localized amelogenesis imperfecta. Others have indicated that there is a possible association between MIH and variants in genes related to enamel formation such as AMBN, TUFT1, and TFIP11 [7,8]. A genome-wide association study identified the SCUBE1 gene on chromosome 22 as a potential genetic locus for MIH [9].

There is wide disparity in the reported prevalence figures of MIH. The majority of reports are from European populations, with prevalence rates ranging from 5.9% to 38% [10,11]. Other Non-European prevalence data also demonstrate extreme variations with a prevalence rate as low as 2.8 % in Hong Kong [12] and a rate as high as 40.2% in

Brazilian children [13]. The extensive variation in the described rates is suggested to be either due to actual differences in MIH prevalence between different populations, variations in age cohorts, masking of MIH by other conditions, or most importantly, due to the different clinical examination protocols used to define this condition and the non-uniform methods of classification and scoring indices [14-17]. The objective of the current review was to systematically evaluate the studies on MIH to determine the consistency of the use of the current definition and scoring systems.

Methods

A broad search of MEDLINE, EMBASE, ResearchGate, and Google Scholar databases was conducted for the years 2001 to 2015, using the index terms 'molar-incisor-hypomineralization', 'MIH', 'idiopathic enamel defects in permanent teeth', 'hypomineralized permanent molars' and 'hypomineralized permanent incisors'. The search was limited to English language articles. All abstracts were read and the full text of available relevant articles was then reviewed and data were extracted by two authors independently. The reference list

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of key articles was also examined to include any citations that were not located in the search engines.

Of the 175 initial citations, 94 were selected based on abstracts and the remaining articles dealing with generalized enamel defects or inherited dental anomalies were excluded. After reviewing each publication, 52 articles (40 research paper and 12 reviews) relevant to the formulated research question were chosen for inclusion.

Articles were included if the aim was either to describe MIH

including a contemporary definition and scoring system or to estimate the prevalence in a certain population excluding articles focusing on generalized or hereditary enamel defects and other age groups.

Results

Criteria of the 52 articles included in the current review (12 reviews and 40 clinical prevalence studies) are summarized in Tables 1 and 2.

A total of 25 reports used either Weerheijm *et al.* [1] or Weerheijm

Table 1. Summary of included articles.

	Study	Year	Study type	Location	Classification	Definition
1	Weerheijm <i>et al.</i> [1]	2001	Short communication	Amsterdam, The Netherlands	The aim of this report was to describe the phenomenon and find a common name for it	Hypomineralization of systemic origin of 1-4 permanent first molar, frequently associated with affected incisors
2	Weerheijm [2]	2003	Review	Amsterdam, The Netherlands	Not provided	Weerheijm <i>et al.</i> [1]
3	Weerheijm <i>et al.</i> [3]	2003	Review and experts meeting conclusions	Amsterdam, The Netherlands	Judgement criteria were set as: - absence or presence of demarcated opacities; - PEB; - atypical restorations; - extraction of molars due to MIH; - failure of eruption of a molar or an incisor	Weerheijm <i>et al.</i> [1]
4	William <i>et al.</i> [38]	2006	Review	Melbourne, Australia	Weerheijm <i>et al.</i> [3]	Weerheijm <i>et al.</i> [1]
5	Mathu-Muju and Wright [39]	2006	Chapter	North Carolina, USA	-Mild MIH: Demarcated opacities in nonstress-bearing area, isolated, no fracture, no hypersensitivity or caries. -Moderate MIH: Intact atypical restorations, demarcated opacities on occlusal/incisal third of teeth without PEB, PEB or caries limited to 1 or 2 surfaces without cuspal involvement. -Severe MIH: PEB, history of sensitivity, caries, crown destruction, defective atypical restoration, esthetic concerns	Weerheijm <i>et al.</i> [1]
6	Crombie <i>et al.</i> [18]	2009	Review	Melbourne, Australia	DDE Index	Demarcated, qualitative defects of enamel of systemic origin, affecting one or more permanent molars [usually FPMs] with or without involvement of the incisor teeth
7	dos Santos and Maia [40]	2012	Chapter	Rio de Janeiro, Brazil	The 10-point scoring system based on the EAPD criteria (Ghanim <i>et al.</i> [16])	Morphological enamel defects involving the occlusal and/or incisal third of one or more permanent molars or incisors as result of hypomineralization of systemic origin
8	Sadashivmurthy and Deshmukh [41]	2012	Review	Karnataka, India	Weerheijm <i>et al.</i> [3]	Acquired developmental defect primarily disrupting mineralization of permanent first molars and incisors
9	Shubha and Hedge [5]	2013	Review	Rajasthan, India	Weerheijm <i>et al.</i> [3]	Weerheijm <i>et al.</i> [1]
10	Seow [42]	2014	Review	Brisbane, Australia	Not provided	A condition where the permanent molars and incisors show demarcated areas of hypomineralization or opacities and often have PEB of the weak tooth structure and show high susceptibility to caries
11	Bajwa <i>et al.</i> [43]	2014	Review	Andhra Pradesh, India	Weerheijm <i>et al.</i> [3]	Weerheijm <i>et al.</i> [1]
12	Ghanim <i>et al.</i> [17]	2015	Review	Melbourne, Australia	A detailed diagnostic chart was proposed combining both clinical presentation of the enamel lesion and the size of the surface area affected: 0: no visible enamel defect; 1: enamel defect, non-MIH, 2: White creamy demarcated, yellow or brown demarcated opacities; 3: PEB; 4: Atypical restoration; 5: Atypical caries; 6: Missing because of MIH; 7: Cannot be scored. Lesion extension criteria (after diagnosing i.e. scores 2 to 6): I: less than one third of the tooth affected; II: at least one third but less than two thirds of the tooth affected; III: at least two thirds of the tooth affected	Weerheijm <i>et al.</i> [1]

PEB: posteruptive enamel breakdown; PFM: permanent first molar; EAPD: European Academy of Pediatric Dentistry; DDE: developmental defects of enamel index

Table 2. Summary of included studies.

	Study	Year	Study type	Location	Sample	Scoring	Definition
1	Calderara <i>et al.</i> [32]	2005	Prospective cohort	Lissone, Italy	Total: 227 children, age 7.3-8.3 years, MIH: 13.7%	Weerheijm <i>et al.</i> [1]	Weerheijm <i>et al.</i> [1]
2	Fteita <i>et al.</i> [22]	2006	Prospective cohort	Benghazi, Libya	188 children, age 7-8.9 years, MIH: 2.9%	- Mild : color changes of smooth surface - Moderate : loss of enamel without dentine involvement - Severe : lesions affecting both the enamel and the dentine, atypical restorations and teeth extracted because of severe hypomineralization	Weerheijm <i>et al.</i> [1]
3	Preusser <i>et al.</i> [10]	2007	Prospective cohort	Giessen, Germany	Total: 1,002 children, age 6-12 years, MIH: 5.9%	• Degree 1 : Isolated white, cream, yellowish-brown discolorations on the chewing surface and upper part of the crown • Degree 2 : hypomineralized yellowish-brown enamel affecting the humps on the top of the crown, but with only a slight loss of substance • Degree 3 : Large-scale mineral deficiency with distinct yellowish brown discolorations and defects in crown morphology resulting from extensive loss of enamel.	Enamel defects in first permanent molars and permanent incisors, ranging from distinct, isolated, white, and cream-colored markings to large-scale ill structuring
4	Jasulaityte <i>et al.</i> [44]	2007	Prospective cohort	Kaunas, Lithuania	Total: 1,277 children, age 7-9 years, MIH: 9.7%	MIH cases were categorized into three groups (opacities, enamel breakdown, and atypical restorations) and were recoded into two severity levels: opacities and disintegration defects. The affected children were divided into two groups: children having 1-2 affected teeth and children having 3-6 affected teeth	Weerheijm <i>et al.</i> [1]
5	Muratbegovic <i>et al.</i> [33]	2007	Cross-sectional case-control study	Sarajevo, Bosnia and Herzegovina	Total: 560 children, 12 years old, MIH: 12.3%	EAPD [3]	The systemic hypomineralization of one, two, three or all four FPM often followed by changes of maxillary and somewhat less commonly of mandibular permanent incisors
6	Jasulaityte <i>et al.</i> [45]	2008	Prospective cohort	Amsterdam, The Netherlands	Total: 442 children, age 6-11 years, MIH: 14.3%	EAPD [3]	Weerheijm <i>et al.</i> [1]
7	Lygidakis <i>et al.</i> [25]	2008	Prospective cohort	Athens, Greece	Total: 3518 children, age 5.5-12 years, MIH: 10.2%	- Mild defects : demarcated opacities - Moderate/severe defects : PEB and atypical restorations	Weerheijm <i>et al.</i> [1]
8	Laisi <i>et al.</i> [23]	2008	Prospective cohort	Helsinki, Finland	Total: 167 children, age 7-10 years, MIH: 14.4%	- Mild defects : Demarcated opacity larger than 2 mm in diameter - Moderate defects : Broken enamel - Severe defects : Loss of enamel with affected dentine, or atypical restoration	Weerheijm <i>et al.</i> [1]
9	Whatling and Fearne [46]	2008	Prospective cohort	London, UK	Total: 109 children, age 6-13 years, MIH: 57 children	Not provided	Weerheijm <i>et al.</i> [1]
10	Cho <i>et al.</i> [12]	2008	Retrospective cross-sectional	Hong Kong	Total: 2635 records, 12 years old, MIH: 2.8%	The severity of hypomineralization was not recorded	Weerheijm <i>et al.</i> [1]
11	Kusku <i>et al.</i> [47]	2008	Retrospective clinical study	Istanbul, Turkey	Total: 147 children, age 7-9 years, MIH: 14.9%	EAPD [3]	Weerheijm <i>et al.</i> [1]
12	Chawla <i>et al.</i> [27]	2008	Retrospective cross-sectional	Melbourne, Australia	Records of 182 MIH children, age 6-14 years	- Mild defects : Teeth with white-cream opacities - Moderate-severe : Yellow-brown discoloration or PEB hypomineralization	Weerheijm <i>et al.</i> [1]
13	Chawla <i>et al.</i> [28]	2008	Retrospective cross-sectional	Melbourne, Australia	Records of 182 MIH children, age 6-14 years	Hypomineralization Severity Index. (Chawla <i>et al.</i> 2008) * Presence: FPM unerupted = 0; FPM erupted = 1. * Extent of hypomineralization: none = 0; mild = 1; moderate-severe = 2. * Sensitivity: none = 0; sensitive = 1. * No. restorative procedures: none = 0; one = 1; two = 2; three or more = 3	Weerheijm <i>et al.</i> [1]

14	Laisi <i>et al.</i> [48]	2009	Prospective cohort	Lammi, Finland	Total: 141 children, age 7.8-12.7 years, MIH:16.3%	- Mild defects: demarcated opacity - Severe defects: PEB/atypical restorations replacing affected enamel	Weerheijm <i>et al.</i> [1]
15	Kuscu <i>et al.</i> [49]	2009	Prospective cohort	Kocaeli, Turkey	Total: 153 children, age 7-10 years, MIH: 9.1-9.2%	EAPD [3]	Weerheijm <i>et al.</i> [1]
16	Kemoli [26]	2009	Prospective cross-sectional	Nairobi, Kenya	Total: 3,591 children, age 6-8 years, MIH: 13.73%	0: No opacities or discolorations, 1: Demarcated opacities, PEB, large and extensive restorations suspected to be a result of hypomineralization.	Weerheijm <i>et al.</i> [1]
17	Soviero <i>et al.</i> [13]	2009	Prospective cohort	Rio de Janeiro, Brazil	Total: 249 children, age 7-13 years, MIH: 40.2%	0: Absence of demarcated opacity 1: Presence of a demarcated opacity, PEB, an atypical restoration, or extraction due to demarcated opacities	Demarcated opacities which are qualitative defects involving an alteration in the translucency of the enamel, which is otherwise normal in terms of thickness and smoothness of its surface often affecting PFM
18	da Costa-Silva <i>et al.</i> [24]	2010	Prospective cohort	Araraquara-SP, Brasil	Total: 918 children, age 6-12 years, MIH: 19.8%	- Mild: demarcated opacities larger than 1.0 mm with no need of treatment - Moderate: lesions with rough and broken enamel - Severe: loss of dental structure affecting both enamel and dentin, atypical restorations replacing affected hard tissue or teeth extracted because of severe hypomineralization	Weerheijm <i>et al.</i> [1]
19	Ghanim <i>et al.</i> [16]	2011	Prospective cohort	Mosul, Iraq	Total: 823 children, age 7-9 years, MIH: 18.6%	0: Enamel defect free; 1: White /creamy demarcated opacities, no PEB; 1a: White /creamy demarcated opacities, with PEB; 2: Yellow /brown demarcated opacities, no PEB; 2a: Yellow /brown demarcated opacities, with PEB; 3: Atypical restoration; 4: Missing because of MIH; 5: Partially erupted with evidence of MIH; 6: Unerupted /partially erupted with no evidence of MIH; 7: Diffuse opacities (not MIH); 8: Hypoplasia (not MIH); 9: Combined lesion (diffuse opacities / hypoplasia with MIH); 10: Demarcated opacities in incisors only	Weerheijm <i>et al.</i> [1]
20	Brogardh-Roth <i>et al.</i> [11]	2011	Cross-sectional case-control study	Malmo, Sweden	Total: 82 children, age 10-12 years, MIH: 38%	- Mild: Hard, normal surface white, creamy, yellow or brown defects - Moderate: Minor loss of substance with no need of restoration - Severe: disintegration of enamel and needed restoration, or atypical restoration	A demarcated opacity with a diameter exceeding 2 mm, or PEB/ atypical restoration/ extraction as a result of MIH in the permanent first molars
21	Zawaideh <i>et al.</i> [35]	2011	Prospective cross-sectional	Irbid, Jordan	Total: 3241 children, age 7-9 years, MIH:17.6%	EAPD [3]	Weerheijm <i>et al.</i> [1]
22	Elfrink <i>et al.</i> [50]	2012	Prospective cohort	Rotterdam, the Netherlands	Total: 6161, age 6-12 years, MIH: 8.7%	EAPD [3]	Weerheijm, <i>et al.</i> [1]
23	Ahmadi <i>et al.</i> [51]	2012	Prospective cohort	Zahedan, Iran	Total: 433, age 7-9 years, MIH: 12.7%	DDE index	Weerheijm <i>et al.</i> [1]
24	Martinez Gomez <i>et al.</i> [52]	2012	Prospective cohort	Barcelona, Spain	Total: 505 children, age 6-14 years, MIH: 17.85%	Mathu-Muju and Wright [39]	Weerheijm <i>et al.</i> [1]
25	Balmer <i>et al.</i> [21]	2012	Prospective cohort	Leeds, UK	Total: 3233 children, 12 years old, MIH:15.9%	mDDE	A pattern of enamel defects that consist of asymmetric, well-demarcated opacities affecting the FPMs and is associated with similar defects in permanent incisors and canines
26	Parikh <i>et al.</i> [53]	2012	Prospective cross-sectional	Gujarat, India	Total: 1366 children, age 8-12 years, MIH: 9.2%	- Mild: demarcated enamel opacities without enamel breakdown, occasional sensitivity to external stimuli and only mild esthetic concerns - Severe: demarcated enamel opacities with breakdown, caries, persistent/ spontaneous hypersensitivity affecting function	Weerheijm <i>et al.</i> [1]

27	Souza <i>et al.</i> [54]	2012	Prospective cohort	São Paulo, Brazil	Total: 903 children, age 6-12 years, MIH: 24.9% and 17.8%,	EAPD [3]	Weerheijm <i>et al.</i> [1]
28	Jeremias <i>et al.</i> [55]	2013	Cross-sectional observational	São Paulo, Brazil	Total: 1157 children, age 6-12 years, MIH: 12.3%	- Mild : demarcated enamel opacities of different colors either white, yellow and brown - Severe : PEB, atypical restorations and extraction due to MIH	Weerheijm <i>et al.</i> [1]
29	Sönmez <i>et al.</i> [34]	2013	Prospective cohort	Ankara, Turkey	Total: 4049 children, age 7-12 years, MIH: 7.7%	EAPD [3]	Weerheijm <i>et al.</i> [1]
30	Mittal <i>et al.</i> [14]	2014	Prospective cross-sectional	Chandigarh, India	Total: 1792 children, age 6-9 years, MIH: 6.31%	The 10-point scoring system based on the EAPD criteria (Ghanim <i>et al.</i> [16])	Weerheijm <i>et al.</i> [1]
31	Saldias-Vargas <i>et al.</i> [56]	2014	Prospective cohort	Bauru, Brazil	Total: 150, age 6-12 years, MIH: 4%, 22%, 42% for non-cleft, cleft palate, and cleft lip and palate groups respectively	mDDE index	Enamel defects in PFMs combined with hypomineralized incisors
32	Garcia-Margarit <i>et al.</i> [57]	2014	Prospective cross-sectional	Valencia, Spain	Total: 840 children, 8 years old, MIH: 21.8%	0 – Permanent teeth free of pathological conditions, M – MIH O : Demarcated opacities >2 mm diameter P : Post-eruption enamel breakdown C : Extensive caries with opacities around edge R : Atypical restorations. E : Missing permanent first molars as a result of MIH N : Tooth not erupted	Weerheijm <i>et al.</i> [1]
33	Shrestha <i>et al.</i> [58]	2014	Prospective cross-sectional	Kavre, Nepal	Total: 749 children, age 7-12 years, MIH: 13.7%	10-point scoring system based on EAPD criteria (Ghanim <i>et al.</i> 2011) Unerupted tooth was considered as not having MIH; thus code 6 was also considered as code 0. Also, both the white/creamy demarcated opacities, with PEB and yellow/brown demarcated opacities, with PEB were included in the group of teeth with PEB	Weerheijm <i>et al.</i> [1]
34	Jankovic [59]	2014	Retrospective cross-sectional	Foča, Bosnia and Herzegovina	Total: 141 children, 8 years old, MIH: 12.8%	- Mild : Enamel color changes (white, yellow or brown) - Moderate : discoloration and minimal loss of tooth substances without the need for restoration - Severe : damaged enamel and dentin loss that require restoration	Weerheijm <i>et al.</i> [1]
35	Petrou <i>et al.</i> [60]	2014	Prospective cohort	Greifswald, Germany	Total: 2395 children, age 8-9 years, MIH: 10.1%	Mild or severe alteration according to the degree of tooth structure loss	Weerheijm <i>et al.</i> [1]
36	Ghanim <i>et al.</i> [19]	2014	Prospective cohort	Shiraz, Iran	Total: 810 children, age 9-11 years, MIH: 164 (20.2 %)	- Mild : color changes only (i.e. creamy white or yellow/brown) - Moderate : loss in enamel substance - Severe : loss of enamel associated with affected dentine and/or atypical restoration	The clinical presence of developmental defects that can be seen as opacities, discoloration or as a mixture of change in appearance and loss of enamel substance. The PFMs and permanent incisors have been reported as the most frequently affected teeth, however, any other tooth, primary or permanent, may be affected at the same time
37	Krishnan <i>et al.</i> [61]	2015	Prospective cohort	Tamilnadu, India	Total: 4989 children, age 9-14 years, MIH: 7.3%	The 10-point scoring system based on the EAPD criteria (Ghanim <i>et al.</i> [16])	Weerheijm <i>et al.</i> [1]
38	Hussein <i>et al.</i> [62]	2015	Prospective cohort	Selangor, Malaysia	Total: 154 children, age 7-12 years, MIH: 16.9%	- Mild : Enamel color changes (white, yellow or brown) - Moderate : discoloration and minimal loss of tooth substances without the need for restoration - Severe : damaged enamel and dentin loss that require restoration	Weerheijm <i>et al.</i> [1]

39	Oyedele <i>et al.</i> [63]	2015	Prospective cross-sectional	Ile-Ife, Nigeria	Total: 2,107 children, age 8-16 years, MIH: 12.7%	- Mild : Demarcated opacities present in the non-stress bearing areas of the molars with no enamel loss from fracturing - Moderate : Atypical restoration, demarcated opacities present on the occlusal/incisal third of the teeth with no PEB or with PEB limited to one or two surfaces without cuspal involvement - Severe : PEB	Weerheijm <i>et al.</i> [1]
40	Kevrekidou <i>et al.</i> [20]	2015	Prospective cross-sectional	Thessaloniki, Greece	Total: 2335 children, age 8-14 years, MIH: 21%	- Mild : Demarcated enamel opacities, occasional sensitivity to external stimuli, and only mild esthetic concerns - Severe : Demarcated enamel opacities with PEB, hypersensitivity affecting function, and strong esthetic concerns	The developmental phenomenon in which one to four PFMs and possibly incisors appear with demarcated opacities due to enamel hypomineralization

PEB: posteruptive enamel breakdown; PFM: permanent first molar; EAPD: European Academy of Pediatric Dentistry; DDE: developmental defects of enamel index

et al. [3] definition and scoring system. The most commonly used definition in literature, in general, was the original definition created by Weerheijm *et al.* [1]: “Hypomineralization of systemic origin of 1-4 permanent first molars frequently associated with affected incisors”. Weerheijm *et al.* [3] characterized the hypomineralization as a demarcated opacity, not diffuse. Some authors, however, modified the definition of hypomineralization to include other clinical criteria such as “color changes or ill structuring” or changing the word “systemic origin” into developmental, qualitative, morphological, or asymmetrical [10,13,18-20]. Some authors also included other teeth such as the permanent canines, permanent second molars, or primary teeth in the definition [19,21].

While some of the prevalence reports indicated that they used the EAPD criteria or the modified developmental defects of enamel (DDE) index as their classification system, other authors have either added modifications or created their own judging criteria. For example, Fteita *et al.* [22], Laisi *et al.* [23], and da Cost-Silva *et al.* [24] classified their cases into mild, moderate, or severe according to the degree of tooth structure loss. Lygidakis *et al.* [25] and Kevrekidou *et al.* [20] suggested that it's better to classify MIH cases into two groups only (mild and severe) combining the previously designed two categories of moderate and severe into one group. Some investigators [13,26] based their data only on a classification of 0 and 1, where 0 indicates sound teeth or a normal dentition while 1 denotes MIH affected case without reporting grading or severity.

Discussion

MIH can affect both esthetics and cariogenic susceptibility and is considered to be a global dental problem. It is described by the EAPD as hypomineralization of systemic origin of 1-4 first permanent molars (FPM) frequently associated with affected incisors [3]. Since then, the defining criteria for the condition seem to be the systemic origin and the demarcated opacities in FPM with or without associated incisors. Clinically, MIH presents as opacities of different colors in the affected teeth that will sometimes undergo post-eruptive breakdown due to the porous and weak enamel surface. Accordingly, the condition can represent a serious and challenging clinical management problem. Children with MIH require higher levels of treatment needs and demonstrate considerable management problems [27-29]. Although most of the published research is epidemiological data, there is still insufficient evidence about the significance of consequences of MIH and how it may impact the dental healthcare delivery system in general.

Based on these review findings, there seems to be many reasons why the current MIH terminology and criteria are considered questionable and should be addressed:

Teeth involved

In some reports, demarcated opacities were not limited to the permanent first molar and incisors. Similar lesions have been observed on second primary molars, permanent canines, second permanent molars and premolars [19,21]. Consequently, some authors [30] described the terminology MIH as “misleading” and claimed that this greatly contributes to an under-estimation of the actual defect. They suggested that mineralization defects on all teeth should be recorded in order to reflect the extent of involvement and if sufficient evidence exist that MIH is not predominantly restricted to molars and incisors, revising the name should be considered.

While most of the studies consider children as having MIH when one or more FPM meet the diagnostic criteria, others [21] indicated that in the absence of FPMs, MIH diagnosis should be based on the anterior teeth. Balmer *et al.* [31] introduced other terms such as Incisor Hypomineralization (IH) and Molar Hypomineralization (MH). They indicated that the definition of all three conditions (MIH, IH and MH) are mutually exclusive and that demarcated opacities named as IH, MH, and deciduous molar incisor hypomineralization (DMH) should all be considered parts of a spectrum that includes MIH given that these defects share characteristics and risk factors which overlap with MIH and are expected to have the same etiology. The original inclusion of only molars and sometimes incisors was based on the mixed dentition status of the children examined. These teeth form and erupt earlier than the other permanent teeth and could show either early environmental effects or staged genetic effects on tooth formation. We agree with Weerheijm *et al.* [3] that if examinations of older children could show that more teeth are involved in hypomineralization than the molars and incisors, then a name change would be appropriate.

Lesion size

The minimum size of lesions included in the diagnosis of MIH is also inconsistent between studies. While some studies included only defects larger than 2 mm [16,32-34], others have included all hypomineralized lesions regardless of their size [30,35]. The exclusion of smaller defects might have thus contributed to lower prevalence rates in some reports.

Severity indices or scoring systems

The majority of published literature basically report prevalence data in certain population. Prevalence figures varied considerably. To a great extent, the lack of standardization and heterogeneity of the scoring or characterization systems used in each study probably contributed to the variability. Although a few studies used the current

EAPD characterizing system (Table 3), some authors have either used some modifications or created their own scoring system which makes it obvious that there is a certain degree of confusion and lack of consensus [3,22-26]. The usefulness of the early EAPD criteria should also be reevaluated due to the fact that it only categorizes the enamel conditions but does not quantify them. Ghanim *et al.* [17], following the 2014 EAPD Congress in Poland, developed a complex scoring system to quantify the severity of MIH based on the number of involved teeth as well as the type and extent of the enamel defect.

The severity of MIH may differ significantly between individuals and within different teeth of the same individual. The DDE index was implemented to classify the affected teeth according to the type and extent of the defect into 3 categories: demarcated opacities, diffuse opacities, or hypoplasia. Modifications were later proposed to make classification simpler while more specific and meaningful (Table 4).

According to current EAPD criteria, the most extensively used index, diagnosis of MIH includes recording either absence or presence of demarcated opacities, post-eruptive enamel breakdown, atypical restorations, extractions due to MIH and the failure of eruption of a molar or incisor. The use of different scoring systems and severity indices results in confusing and contradictory results. If a case was only scored according to the most severe defect, this may not reflect meaningful results as it may represent involvement of a few or even one tooth whereas the same score may be given to a case with multiple minor defects in another study using summation of scores of all affected teeth. This inconsistency does not allow accurate representation of the

patients' overall oral condition, actual restoration needs, and financial requirements.

Children with MIH have higher levels of treatment needs and satisfactory restoration of affected teeth might be very challenging. A study reported that by the age of nine years, children affected with enamel hypomineralization required dental treatment about ten times more frequently compared to unaffected children and that each hypomineralized tooth was treated on average twice [36]. Actual management needs were underestimated when considering only decayed or restored teeth as most of these children would also require continued pediatric restorative, orthodontic and preventive care [37,38]. This highlights the importance of directing future research to high-quality studies that help to improve our understanding of the exact causes of MIH, allow development of standardized diagnostic criteria and universal severity index, and update the dental profession on the overall impact on the oral health care delivery system.

Conclusions

Although MIH seems to be a significant dental public health concern, there is insufficient evidence regarding how accurate the currently used definition and judgement criteria reflect the clinical challenges, treatment needs, and cost associated with the condition. Studies continue to be published using alternative definitions and scoring systems and there is lack of agreement on important criteria. Such inconsistency makes it difficult to compare studies and develop evidence based guidelines. A globally accepted definition and scoring system is necessary.

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Table 3. Diagnostic criteria for MIH [3].

Each tooth should be examined for:	
1	Absence or presence of demarcated opacities (defect altering the translucency of the enamel)
2	Posteruptive enamel breakdown (loss of surface enamel after tooth eruption, usually associated with a pre-existing opacity)
3	Atypical restorations (frequently extended to the buccal or palatal smooth surfaces reflecting the distribution of hypoplastic enamel)
4	Extracted molars due to MIH
5	Failure of eruption of a molar or incisor

Table 4. Modified DDE index for use in general purpose epidemiological studies [64].

	Code
Normal	0
Demarcated opacities:	
white/cream	1
yellow/brown	2
Diffuse opacities:	
Lines	3
Patchy	4
Confluent	5
Confluent/patchy + staining+ loss of enamel	6
Hypoplasia:	
Pits	7
Missing enamel	8
Any other defects	9
Extent of Defect:	
Normal	0
< 1/3	1
At least 1/3 < 2/3	2
At least 2/3	3

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