ACTA ODONTOLOGICA SCANDINAVICA
2020, VOL. 78, NO. 7, 535–540
https://doi.org/10.1080/00016357.2020.1751274

Taylor & Francis
Taylor & Francis Group

ORIGINAL ARTICLE

Estimating molar-incisor-hypomineralization among 8-year-olds based on 15-year public oral health practice-based data

Battsetseg Tseveenjav[a,b,c], Jussi Furuholm[a,c], Aida Mulic[c], Håkon Valen[c], Tuomo Maisala[b], Seppo Turunen[b], Sinikka Varsio[b], Merja Auero[d] and Leo Tjäderhane[a]*

[a]Department of Oral and Maxillofacial Diseases, University of Helsinki, and Helsinki University Hospital, Helsinki, Finland; [b]Oral Health Care, Department of Social Services and Health Care, City of Helsinki, Helsinki, Finland; [c]Nordic Institute of Dental Materials (NIOM), Oslo, Norway; [d]Department of Health, Ministry of Social Affairs and Health, Helsinki, Finland

ABSTRACT

Background: A wide range in the prevalence of molar-incisor-hypomineralization (MIH) has been reported. Population-based studies are recommended. However, such studies are expensive and time-consuming.

Objectives: To estimate the magnitude of MIH condition among 8-year-olds based on routine oral health examinations and to associate first permanent molar (FPM) affection with that of other permanent teeth over time.

Materials and methods: This retrospective study, with cross-sectional and longitudinal components, was based on electronic oral health records; all 8-year-olds examined between 2002 and 2016 were included.

Results: The average estimated prevalence of MIH was 8.3%; yearly range was 4.8–15.9%. The mean number of affected teeth was 1.4; 62% had one affected tooth. One-surface defects were the most frequent (66%). Asymmetric distribution of affected teeth was observed. In follow-up, 10.7%, 8.4%, and 11.2% had at least one affected permanent canine, premolar, or second permanent molar, respectively. The proportion of children with other MIH-affected permanent teeth was higher in the group with $\geq$2 MIH-affected teeth than in group with one affected FPM at the age of 8.

Conclusions: The average prevalence of MIH was comparable to that reported elsewhere. The number of MIH-affected teeth at early mixed dentition predicts the affection of other permanent teeth over time, mainly that of permanent canines. Further screening of children with MIH is recommended to improve individually tailored early preventive and restorative dental care.

ARTICLE HISTORY
Received 6 January 2020
Revised 27 February 2020
Accepted 23 March 2020

KEYWORDS
Prevalence; molar-incisor-hypomineralization; practice-based data; children; MIH affection of permanent canines

Introduction

Molar-incisor-hypomineralization (MIH) is a dental developmental defect (DDD) of systemic origin of one or more first permanent molars (FPMs). MIH is frequently associated with a similarly affected permanent incisor(s) (PIs) [1]. To diagnose MIH, at least one FPM is required to be affected [2] regardless of involvement of PIs. MIH defects have also been observed in second primary molars, tips of permanent canine cusps, and second permanent molars [2–4].

MIH is a multifactorial condition due to a variety of systematically acting environmental factors, including prenatal, perinatal, and postnatal conditions [1,5–11] with a possible underlying genetic predisposition [12]. Despite increasing knowledge, the aetiological evidence for MIH is insufficient to verify the proposed causative factors [13].

MIH-affected teeth present demarcated enamel opacities (DEOs) of different colours, from white to yellowish up to brown that occasionally undergo post-eruptive breakdowns [14]. DEOs are the most frequently encountered enamel defect among Swedish adolescents [15]; DEOs were 27% of the overall DDD prevalence (33%), while the prevalence of diffuse opacities and enamel hypoplasia were 5% and 1%, respectively. Among Danish children of 6–8 years, nearly half had DEOs in FPMs or PIs [16].

A wide range in the prevalence of MIH (2.8–44%) has been reported. The estimated prevalence among different continents is 8.3% in Africa, 12.9% in Asia, 16.2% in Europe, 24.9% in Oceania, and 30% in South America [17]. The wide range of prevalence rates may be due to differences in the age of the population, examination standards, chosen index, or calibration. In two recent meta-analyses, the average global prevalence of MIH was estimated at 13.1% [18] with significant differences between regions and countries and 14.2% [19] with no significant difference between boys and girls. Heavily populated countries contribute significantly to the prevalence, while growing ones rank first with respect to the incidence [18].

In Nordic countries, the prevalence of MIH among Swedish cohorts of 11, 15, and 19 years was 17.1%, 11.2%

CONTACT Battsetseg Tseveenjav battsetseg.tseveenjav@helsinki.fi Department of Oral and Maxillofacial Diseases, University of Helsinki, P.O.B 41, Mannerheimintie 172, Helsinki, 00014, Finland
*Research Unit of Oral Health Sciences, and Medical Research Center Oulu, Oulu University Hospital and University of Oulu, Oulu, Finland

and 8.3%, respectively [15]. The prevalence was among Norwegian adolescents of 16 years 13.9% [3] and Finnish rural children (mean age 10 years) 11.5% [20].

The Best Clinical Practice Guidance of the European Association of Paediatric Dentistry [2] recommends future population-based studies on the prevalence of MIH; the best group for a cross-sectional study is children of 8 years. However, population-based epidemiological studies are expensive and time-consuming, and therefore, the aim of the present study was to estimate for the first time the prevalence of MIH among children of 8 years that attended public oral health services in Helsinki based on 15-year cross-sectional practice-based data. In addition, MIH affection of other permanent teeth (other than FPM and PI) based on longitudinal follow-up of selected children was assessed over time.

Material and methods

This study was based on the large database of electronic health records of the Oral Health Care (OHC) of the City of Helsinki from 2002 to 2016. In Finland, as in other Nordic countries, oral health care is characterized by a large public sector that is subsidized by taxation and administered by municipalities. Thus, the OHC in Helsinki organizes the public oral health services for all inhabitants residing in the Helsinki area. All children and adolescents under 18 years are entitled to services without charge, including oral health examinations and treatments.

As the present study is a health register-based study, data were collected retrospectively from patient records of routine oral health examinations of children attending public health service. Data mining approach was used to collect the data of all children attending the city of Helsinki Public OHC service from the electronic patient health record system 'EFFICA' (Tieto Oyj, Espoo, Finland). Encrypted summary data of all the visits, extracting all the variables included in the manuscript, was created and exported into Excel file and further into statistical software programme file. Both practicing dentists and dental hygienists performed the oral health examinations and registered all clinical findings in the dental status chart, including caries and DDDs at the surface level of each tooth. Dental hygienists were required to consult dentists in case of doubt. Clinical examinations were carried out with well-equipped dental treatment unit with saliva suction and illumination, with examiners using a dental mirror and fibre optic light, while teeth surfaces being slightly wet. There was not any prior calibration of the examiners regarding registration of DDDs. However, examiners followed detailed guidelines to record findings of clinical oral examinations in the electronic patient records,.

For the cross-sectional component of this study, all children of 8 years undergoing oral health examinations between 2002 and 2016 were selected. Of this cohort, children with a MIH defect recorded in at least one FPM were eligible; the selected age was based on the recommendation of the Best Clinical Practice Guidance of EAPD [2]. Based on these criteria, 3042 children with MIH were selected. There were no children with 12 teeth affected (all FPMs and IPs at the same time), which thus excluded the possibility of major dental developmental conditions related to general health. The estimated prevalence of MIH was calculated for the present study subjects and weighted by gender proportion of the population of 8-year-old children residing in Helsinki (data obtained from Statistics Finland, www.tilastokeskus.fi/index_en.html).

MIH-affected teeth were described by tooth type, jaw location, size, and tooth surface location of the defects. The size of the defects was expressed by the number of tooth surfaces involved.

The inclusion criteria for the longitudinal component of this study were MIH at the age of 8 years and MIH affection of other permanent teeth other than FPMs and PIs in further oral health examinations. To be able to assess other permanent teeth other than FPMs and PIs, children of 8 years with MIH during the observation years 2002–2009 ($n = 2309$) were eligible. Of these, within the framework of our data 1530 had another permanent tooth or other permanent teeth recorded as MIH affected in further oral health examination records between 2007 and 2016. Children in the follow-up group had a theoretical age range of 13–17 years. All teeth with MIH defects registered in examinations at the age of 13–17 years were cumulatively summed. In Finland, children are invited for oral health examinations by dentists or dental check-ups by dental hygienists based on age groups and caries risk and caries activity. Accordingly, not all children have an annual oral health examination. Therefore, to maximize the number of children selected for the follow-up component, an age range was given instead of exact age. The third molars were excluded if such teeth were registered.

Statistical evaluation

The extracted data were compiled into the statistical software package IBM SPSS Statistics for Windows (version 25.0, IBM Corp., Armonk, NY, USA) for statistical analyses. For descriptive statistics, χ^2 test for differences of groups, *t*-test, and one-way ANOVA test for differences of means were used. A Cochran-Armitage test of trend was performed to assess the trend between year of examination and gender. A statistical level of 5% was used for significance.

Ethical considerations

This study was based on encrypted summary data of electronic health records. The use of data for this study was approved by the City of Helsinki in Finland (Research permission decision registration number HEL-2017-000945). Individuals could not be identified, and ethical permission was therefore not applicable.

Results

The average prevalence of MIH among children of 8 years in Helsinki was 8.3%. The range was from 4.8% to 15.9% based on a 15-year observation period (Table 1).

Of all children with MIH, 62% had one affected FPM, followed by 32% with two affected teeth. Table 2 shows the

Table 1. Estimated prevalence of molar-incisor-hypomineralization (MIH) among children of 8 years ($n = 3042$) in Helsinki during 2002–2016.

	Children of 8 years with MIH		Estimated prevalence of MIH in present study population (%)			Weighted estimated prevalence of MIH (%)	
Year	MIH (n)	Boys (n)	All	Boys	Girls	Boys	Girls
2002	400	203	15.9	15.7	16.0	15.9	15.9
2003	267	140	9.1	9.6	8.7	9.3	8.9
2004	155	93	6.3	7.3	5.3	7.2	5.4
2005	288	161	11.6	13.3	10.0	13.1	10.1
2006	238	132	10.8	11.7	9.9	11.7	9.9
2007	246	123	10.6	10.6	10.6	10.5	10.7
2008	189	99	6.3	6.5	6.0	6.5	6.0
2009	152	72	5.9	5.5	6.4	5.5	6.4
2010	188	100	7.3	7.5	7.1	7.4	7.2
2011	186	98	6.9	7.2	6.6	7.2	6.5
2012	125	57	4.8	4.4	5.2	4.3	5.4
2013	132	67	5.3	5.4	5.2	5.3	5.3
2014	167	92	7.5	8.1	6.8	8.1	6.9
2015	135	82	6.1	7.0	5.2	7.2	5.0
2016	174	85	12.0	11.6	12.5	11.6	12.5
All	3042	1604	8.3	8.6	8.0	8.7	8.3

most common MIH-affected single tooth or teeth combinations among children of 8 years. Upper FPMs, namely D16 (35%) or D26 (28%), were the most frequently affected teeth among children with a single tooth affection. Among those with two affected teeth, the most frequent tooth combination was D16 with any other FPM (Table 2).

The mean number of MIH-affected teeth was 1.4 (SD = 0.6; range 1–5). The maxillary teeth were more often affected than the mandibular. An asymmetric distribution of MIH-affected teeth was observed; the right maxillary FPMs were 1.4 times more often affected than the left maxillary FPMs. The right maxillary central incisors were 2.6 times more commonly affected than the left maxillary central incisors. MIH-affected second primary molars were observed in 3.9% of those with MIH condition. One-surface defects were the most frequent (66%), followed by two-surface defects (26%). The most common one-surface defects were located occlusally (36%) or palatally (23%) on D16, occlusally (34%) and buccally (24%) on D26, buccally (38%) and occlusally (28%) on D36, and occlusally (29%) and buccally (28%) on D46. The most common two-surface defects were located palato-occlusally on D16 and D26 (10% in each) and bucco-occlusally on D36 and D46 (18% and 20%, respectively).

Children at follow-up ($n = 1530$) had 3410 MIH-affected teeth (including FPMs and PIs); mean was 2.2 (SD = 1.4). Figure 1 shows MIH-affected teeth of children at follow up as registered at the age of 8 years and in further oral health examinations.

Of all children, 10.7% had at least one permanent canine affected, 8.4% had at least one premolar affected, and 11.2% had at least one second permanent molar affected. The proportion of children with an MIH-affected permanent canine, premolar, or second permanent molar at follow-up was higher among those who had two or more MIH-affected teeth than those with only one FPM affected at the age of 8 years (Figure 2).

Discussion

This study estimated for the first time the prevalence of MIH in the Helsinki area based on population-based electronic health record data. The estimated average prevalence (8.4%) of MIH among children of 8 years in Helsinki based on the 15-year period is consistent with the prevalence reported for children of mean age of 10 years in two rural Finnish towns [20] and Spanish schoolchildren of 6–14 years [9]. However, the observed prevalence was lower than that reported in other Northern European countries, such as Norway [3], Sweden, [15] and Denmark [16]. However, the children's age groups in these studies differed.

The main finding of the longitudinal part of this study was that the number of MIH-affected teeth at the age of 8 years predicted the affection of other permanent teeth over time. This needs to be taken into consideration in tailoring individual dental check-up intervals for children.

Estimation of MIH in Helsinki was far lower than reported prevalence in regions and countries with heavily crowded populations, such as India, China and the United States [18]. The burden of MIH in these countries might be partly explained by socio-environmental differences, such as diet and pollution as well as access to health care.

In the present study was found the typical asymmetric feature of MIH affection in the dentition, which is consistent with the feature seen among Norwegian children [3]. However, the proportion of children with a single tooth or molar affection among MIH children was much higher in our study (62%) than that reported among Norwegian adolescents of 16 years (31.8%) [3].

No gender difference of MIH was observed in our study population. This is consistent with the two reviews, which included 99 [18] and 70 studies [19], respectively, though the former one highlighted observation of higher prevalence in girls than boys in South Asia. Similarly, prevalent cases in girls were also reported among Norwegian adolescents of 16 years [3], and Spanish schoolchildren of 6–14 years [9].

In the present study, only few children had a MIH-affected second primary molar. This is perhaps an underestimation of possible affection of second primary molars, as at this age most primary molars with developmental defects might be restored or extracted. An optimal age of 5 years is recommended for diagnosis of developmental defects in primary molars.

Table 2. Most common MIH-affected tooth or teeth combinations among 8-year-olds ($n = 3042$).

	Most common tooth or teeth combinations	N	% within each group
One tooth affected, $n = 1894$ (62%)	D16	658	35
	D26	536	28
	D36	379	20
	D46	321	17
Two teeth affected, $n = 957$ (32%)	D16 and D26	149	16
	D16 and D46	116	12
	D16 and D36	90	9
	D26 and D46	67	7
	D26 and D36	56	6
	D36 and D46	48	5
	D16 and D11	42	5
	D36 and D11	30	3
	D26 and D11	30	3
	D46 and D11	21	2
	Other combinations (each combination had <21 cases)	308	32
Three teeth affected, $n = 176$ (6%)	D16, D26, and D46	27	14
	D16, D26, and D36	9	5
	D16, D36, and D46	9	5
	D16, D46, and D11	7	3
	D16, D36, and D11	6	3
	Other combinations (each combination had <5 cases)	118	70
Four teeth affected, n = 14 (<1%)	No common combination (14 different combinations)	11	100
Five teeth affected, n = 1 (<0.1%)	Combination: D22, D26, D41, D42, D46	1	100
All		3042	

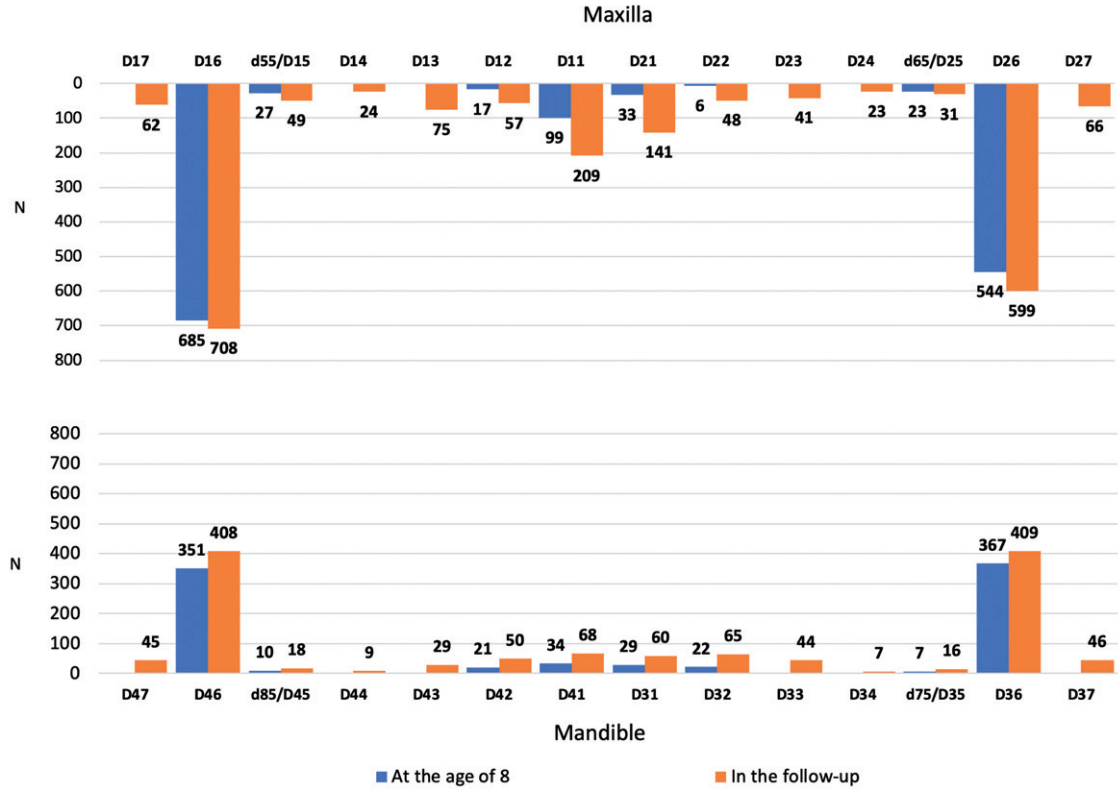

Figure 1. MIH-affected teeth at the age of 8 years and in other permanent teeth over time among children at follow-up ($n = 1530$).

The strength of this study is that the data were obtained from a large population-based database of public service, which practically all children under 18 years attend. According to Statistics Finland, during the years 2002–2016 the yearly cohort of children of 8 years residing in Helsinki ranged from 4820 to 6080 children, with a total cumulative sum of 78,204 children (www.tilastokeskus.fi/index_en.html); of these, 36,753 children were undergoing oral health examinations in the public health care setting. Thus, the prevalence of MIH was based on 47% of the population of 8-year-olds over the 15-year observation period. Therefore, this is a representative estimate of the prevalence of MIH and the magnitude of MIH-affected teeth. Our study population was far larger than the EAPD recommendation for

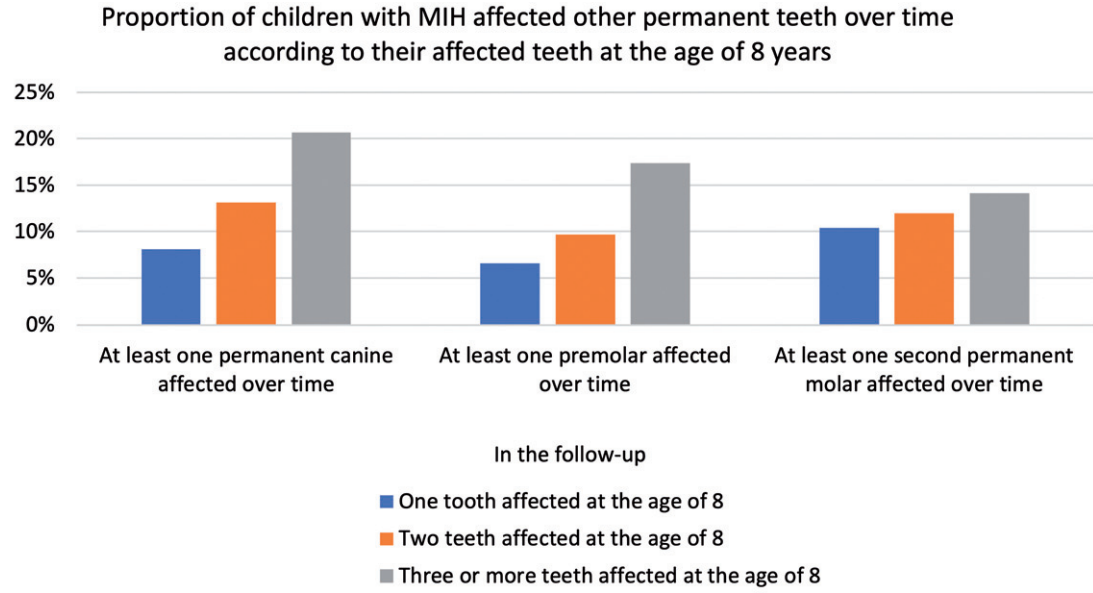

Figure 2. Proportion (%) of children with MIH-affected other permanent teeth at follow-up.

epidemiological studies of MIH, which should be at least 300 individuals [2]. Another strength of this study is the design. Based on 15-year population-based data, the trend of MIH for the entire observation period was explored. The longitudinal follow-up component allowed assessment for the first time the association of MIH-affected teeth of the early mixed dentition period with those of permanent dentition in the same children.

The estimated average prevalence of the present study may be an underestimation as not all defects are necessarily registered due to possible unawareness among dental professionals regarding MIH in general, diagnostic dilemmas the examiner may encounter during oral health examinations, or both. In turn, yearly differences seen in prevalence might be explained partly by variation of clinicians' knowledge and awareness.

On the other hand, the determined prevalence may be an overestimation as other developmental defects such as diffuse opacities and enamel hypoplasia might have been diagnosed as MIH defects, as the former may be confused with the latter with post-eruptive breakdown or onset of caries. However, demarcated opacities are the most common DDDs among children and adolescents [15,16]. It is worth mentioning that even in clinical studies of DDDs, differentiation of tooth tissue loss due to post-eruptive breakdown of demarcated opacities and enamel hypoplasia (which is a quantitative defect of enamel) may be questionable [15].

The limitation of this study is that any misdiagnosis or failure to record MIH defects was handled as they were in patient records, as any other patient record-based study. Therefore, health record-based studies are usually not as precise as epidemiological studies based on clinical examinations. However, the expenses for data collection are far lower and as mentioned above the power of patient-register studies is in high number of examined subjects.

It is worth mentioning also that counting MIH-affected teeth over time was not straightforward. Some new FPMs and especially new PIs with MIH defects were registered at follow up, possibly because of better visibility of all tooth surfaces at later age due to either full eruption of those teeth or improved oral hygiene. This may partly explain the discrepancies in number of MIH teeth at the age of 8 years and in the follow-up.

As caries rates have declined in Western countries during the last decades, DDDs among children are becoming more apparent and require more complex and long-term treatment options [1]. Comparing the prevalence of MIH across countries is a challenging task as the study subjects selected are not homogeneous in age. When assessing the prevalence of MIH at the population level, the age groups need to be well-defined for the purpose.

Conclusions

The average prevalence of MIH among children of 8 years in Helsinki was comparable to that reported elsewhere. The number of MIH-affected teeth at early mixed dentition predicts the affection of other permanent teeth over time, mainly that of permanent canines. An irrelevant number of children had MIH-affected second primary molars. Further screening of children with MIH-affected teeth is recommended to improve individually tailored early preventive and restorative dental care. In this way, an early intervention will facilitate management of further clinical dental problems of MIH-affected teeth and improve oral health-related quality of life of children with this condition.

Acknowledgements

The authors thank Professor Jon E Dahl, managing director of NIOM for valuable comments and support during this project. Author BT thanks the Finnish Dental Society for research grant.

Disclosure statement

The authors report no conflicts of interest. The authors alone are responsible for the content and writing of the paper.

References

[1] Lygidakis NA. Treatment modalities in children with teeth affected by molar-incisor enamel hypomineralisation (MIH): a systematic review. Eur Arch Paediatr Dent. 2010;11:65–74.

[2] Lygidakis NA, Wong F, Jalevik B, et al. Best clinical practice guidance for clinicians dealing with children presenting with molar-incisor-hypomineralisation (MIH): an EAPD policy document. Eur Arch Paediatr Dent. 2010;11:75–81.

[3] Schmalfuss A, Stenhagen KR, Tveit AB, et al. Canines are affected in 16-year-olds with molar-incisor hypomineralisation (MIH): an epidemiological study based on the Tromso study: "Fit Futures. Eur Arch Paediatr Dent. 2016;17:107–113.

[4] Garot E, Denis A, Delbos Y, et al. Are hypomineralised lesions on second primary molars (HSPM) a predictive sign of molar incisor hypomineralisation (MIH)? A systematic review and a meta-analysis. J Dent. 2018;72:8–13.

[5] Silva MJ, Scurrah KJ, Craig JM, et al. Etiology of molar incisor hypomineralization – a systematic review. Community Dent Oral Epidemiol. 2016;44:342–353.

[6] Willmott NS, Bryan RA, Duggal MS. Molar-incisor-hypomineralisation: a literature review. Eur Arch Paediatr Dent. 2008;9:172–179.

[7] Wogelius P, Haubek D, Nechifor A, et al. Association between use of asthma drugs and prevalence of demarcated opacities in permanent first molars in 6-to-8-year-old Danish children. Community Dent Oral Epidemiol. 2010;38:145–151.

[8] Wu X, Wang J, Li YH, et al. Association of molar incisor hypomineralization with premature birth or low birth weight: systematic review and meta-analysis. J Matern Fetal Neonatal Med. 2020; 33(10):1700–1708.

[9] Hernandez M, Boj J, Espasa E, et al. Molar-incisor hypomineralization: positive correlation with atopic dermatitis and food allergies. J Clin Pediatr Dent. 2018;42:344–348.

[10] van der Tas JT, Elfrink MEC, Heijboer AC, et al. Foetal, neonatal and child vitamin D status and enamel hypomineralization. Community Dent Oral Epidemiol. 2018;46:343–351.

[11] Kuhnisch J, Mach D, Thiering E, et al. Respiratory diseases are associated with molar-incisor hypomineralizations. Swiss Dent J. 2014;124:286–293.

[12] Vieira AR, Kup E. On the etiology of molar-incisor hypomineralization. Caries Res. 2016;50:166–169.

[13] Alaluusua S. Aetiology of molar-incisor hypomineralisation: a systematic review. Eur Arch Paediatr Dent. 2010;11:53–58.

[14] Weerheijm KL. Molar incisor hypomineralisation (MIH). Eur J Paediatr Dent. 2003;4:114–120.

[15] Jalevik B, Szigyarto-Matei A, Robertson A. The prevalence of developmental defects of enamel, a prospective cohort study of adolescents in Western Sweden: a Barn I TAnadvarden (BITA, children in dental care) study. Eur Arch Paediatr Dent. 2018;19: 187–195.

[16] Wogelius P, Haubek D, Poulsen S. Prevalence and distribution of demarcated opacities in permanent 1st molars and incisors in 6 to 8-year-old Danish children. Acta Odontol Scand. 2008;66: 58–64.

[17] Hernandez M, Boj JR, Espasa E. Do we really know the prevalence of MIH? J Clin Pediatr Dent. 2016;40(5):259–263.

[18] Schwendicke F, Elhennawy K, Reda S, et al. Global burden of molar incisor hypomineralization. J Dent. 2018;68:10–18.

[19] Dave M, Taylor G. Global prevalence of molar incisor hypomineralisation. Evid Based Dent. 2018;19:78–79.

[20] Wuollet E, Laisi S, Salmela E, et al. Molar-incisor hypomineralization and the association with childhood illnesses and antibiotics in a group of Finnish children. Acta Odontol Scand. 2016;74: 416–422.