Journal of Pre-Clinical and Clinical Research, 2016, Vol 10, No 2, 122-126
www.jpccr.eu

REVIEW ARTICLE

# Molar-Incisor Hypomineralization (MIH) – current knowledge and proposal for therapeutic options

**Marta Marczyńska[1], Rafał Marczyński[2], Renata Chałas[1]**

[1] *Department of Conservative Dentistry and Endodontics, Medical University of Lublin, Poland*
[2] *Department of Prosthodontics, Medical University of Lublin, Poland*

Marczyńska M, Marczyński R, Chałas R. Molar-Incisor Hypomineralization (MIH) – current knowledge and proposal for therapeutic options. J Pre-Clin Clin Res. 2016; 10(2): 122–126. doi: 10.5604/18982395.1227569

## Abstract

**Introduction and objective.** The prevalence of Molar-Incisors Hypomineralization (MIH) and difficulties in diagnosing the disease make it is necessary to determine the exact diagnostic and therapeutic patterns of management. Because of the higher requirements of patients affected by MIH, restorative management of such teeth is a challenge, both for the physician and for the suffering patient.

**Brief description of state of knowledge.** Many long-term randomized studies and meta-analyses clearly indicate that the etiology of occurrence of molar-incisor hypomineralization is multifactorial. Most often it is a combination of systemic and genetic factors. Currently, one of the widely-discussed factors is deficiency of vitamin D as a key factor in the process of enamel development. The study describes current information about Molar-Incisor Hypomineralization, and presents a clinical approach after diagnosis according to protocol which facilities planning of the subsequent stages.

**Conclusions.** The preventive or treatment procedure of MIH should also engage the guardians / parents of the children. The disease undiagnosed in time, due to its pain implications, can lead to problems in dental treatment. Often, the lack of awareness of dentists having no knowledge about the prevalence of MIH, leads to drawing erroneous conclusions and determining therapeutic solutions harmful to the patient, including extraction of the teeth affected by the disease.

## Key words

molar-incisors hypomineralization, MIH, tooth mineralized tissues disorders

## INTRODUCTION

Enamel defects occur due to reduced activity of the enamel-forming ameloblasts during the process of enamel formation, which results in enamel composition disturbances. The disorders depend on the stage of enamel formation in which the noxious factor occurred. If the damaging agents occurred during creation of the enamel matrix (secretion phase), the disorders are called hypoplasia; however, if the change in the structure occurred during the mineralization phase (maturation phase), it is defined as hypomineralization. Once formed, enamel is not remodeled during the lifetime; hence, the resulting changes are not subject to subsequent regression [1]. Hypomineralization of enamel is described as an anomaly associated mainly with tissue translucency (colour change), although abnormalities in normal tissue thickness are not observed [2].

One of the most important forms of lesions is molar-incisor-hypomineralization (MIH), first described in 1970 as a hypomineralization of the permanent first molars (PFMs) [3]. Since then, the nomenclature has been repeatedly changed as well as the way of clinical entity differentiation, but consistently it is referred to as non-fluoride hypomineralization [4, 5]. Finally, in 2001, the term molar-incisor hypomineralization was adopted [4, 5]. Because of the porous and more vulnerable to damage enamel structure affected by MIH, idiopathic disintegration spaces of the tissue may occur on the occlusal surface. These enamel defects are responsible for high-degree sensitivity, secondary caries occupying defective tissues, frequent loss of fillings or restorations, and in extreme cases, loss of a tooth [6, 7, 8].

Because of the higher requirements of the patients affected by MIH, restorative management of such teeth is a challenge, both for the physician and for the suffering patient [9, 10]. The problem in the majority of cases relates to previously undiagnosed children who, due to ailments, demonstrate behavioural problems and far-reaching dental fear. This is often associated with repeated and unsuccessful attempts to achieve an adequate level of anesthesia. Furthermore, the changed and porous structure of the mineralized tooth tissue does not guarantee the production of suitable surface of interface-type (hybrid layer) when bonding systems are used. There are difficulties in the preparation of the most preferred pattern of enamel etching type I (honeycomb) and type II (a pine cone) in the etching process (30 seconds), or over-etching (5 seconds); on the other hand, there is also impeded penetration of adhesive resin through the process of bonding [9, 10, 11, 12].

## OBJECTIVE

The aim of the study was to present current information and propose therapeutic options in Molar-Incisor Hypomineralization, based on literature and own experiences.

**Factors affecting the prevalence of MIH.** There is a large discrepancy in the data on the prevalence of MIH syndrome. It is estimated that the prevalence ranges from 4% – 40%, depending on the race and latitude, and mainly

Address for correspondence: Renata Chałas, Department of Conservative Dentistry and Endodontics, Medical University of Lublin, Poland
E-mail: renata.chalas@umlub.pl

Received: 29 September 2016; accepted: 11 December 2016

environmental factors [7, 9, 10]. It is worth noting that this discrepancy concerns mainly European countries, but there are insufficient statistics on other continents [1, 2, 12, 13].

Each agent acting systemically during prenatal life and during the first three years of a child's life can disrupt the activity of ameloblasts. At the moment when the developed enamel is not subject to the genetically-programmed maturation phase (*remodeling*), each of the environmental factors may leave an irreparable defect in the hard tissue of the tooth [13, 14, 15]. In one study, it was found that every factor affecting the supply and control of oxygen supply to the ameloblast can affect the maturation of enamel and, consequently, condition of the hypomineralization [16]. These factors could include, among others: increased body temperature, chickenpox and prematurity, abnormality in enzymatic pathways in the process of intracellular respiration, intra- and exogenous toxins [16].

Currently, the influence of exposure to bisphenol-A (BPA) during the prenatal period is widely discussed. Bisphenol-A belongs to the group of chemical substances of type EDCs (Endocrine-Disrupting Chemicals) widely used in the production of plastic materials based on epoxy resins and polyols. The World Health Organization (WHO) reports that more than 95% of the population is contaminated with BPA [17, 18]. BPA affects, *inter alia,* impairment of the reproductive function, increase in the prevalence of metabolic syndrome, increase in the incidence of neoplasms, including breast tumours, as well as increase in the frequency of autism [17, 18, 19, 20].

**Diagnostics in MIH syndrome.** The optimal period for examination of patients for the presence of MIH is the age of 8 years. At this age, all molars and permanent incisors are erupted. Additionally, the first molars at this posteruptive period should be in a relatively good state, notwithstanding oral hygiene deficiencies [21]. Assessment should involve the individual examination each of the permanent teeth – in this case, especially the molars and incisors. The MIH diagnostic criteria are currently defined using the modified defect of dental enamel (DDE) index (Tab. 1), based on criteria by Weerheijm et al. [21] (Tab. 2).

**Differential diagnosis.** Permanent teeth with defects of enamel hypoplasia may be confused with MIH. Enamel hypoplasia is a quantitative defect associated with a reduced localized thickness of enamel. Hypomineralization, however, is a qualitative defect affecting enamel translucency, but not affecting its thickness [22, 23]. Diagnostically, MIH and enamel hypomineralization (EH) can be difficult to differentiate when affected molars have posteruptive enamel breakdown (PEB) due to caries or masticatory trauma. In such situations, hypomineralization may be frequently mistaken with hypoplasia as a result of assessment of deficiency of tissues on occlusal surface. However, in hypoplasia, the borders of the deficient enamel are smooth, whereas in hypomineralization the borders with normal enamel are irregular [21, 23]. In children with high caries risk, MIH can be masked by extensive caries or atypical restorations [21, 23]. MIH can also be confused with fluorosis. The enamel opacities of fluorosis are diffuse, in contrast to the well-demarcated borders of hypomineralized enamel seen in MIH [21]. In addition, fluorosed enamel is caries-resistant [21].

**Table 1.** Degrees of Molar-Incisor Hypomineralization

| Degree of MIH severity | Modified DDE index (FDI 1992) |
|---|---|
| Mild | <30% of enamel surface area affected by MIH |
| Moderate | 31 – 49% of enamel surface area affected by MIH |
| Severe | > 50% of enamel surface area affected by MIH |

**Table 2.** Diagnostic criteria of Molar-Incisor Hypomineralization

| Definitions of the criteria used for diagnosing MIH (Weerheijm et al. 2001) | |
|---|---|
| Criteria | **Definitions** |
| Opacity | A defect involving an alteration in the translucency of the enamel. The defective enamel is of normal thickness with a smooth surface and can be white, yellow or brown in colour. The border of the lesions is demarcated. |
| PEB (posteruptive enamel breakdown) | A defect that indicates deficiency of the surface after eruption of the tooth. This may be caused by such factors as trauma and attrition (physiological or pathological). |
| Atypical restoration (iatrogenic factor) | Size and shape of restoration do not conform to typical restorative characteristics. In most cases, restorations will be extended to the buccal or the palatal smooth surface. At the border of the restoration, opacity may be noticed. |
| Extraction due to MIH | Absence of the first permanent molar in a sound dentition is suspected to have been an MIH molar (necessary detailed past history). |

**Clinical symptoms associated with MIH.** The characteristic features of clinical MIH include:
- large demarcated opacities, whitish-cream, yellow or yellow-brown in colour;
- may or may not be associated with posteruption enamel breakdown (PEB);
- extraordinary hypersensitivity of teeth affected by pathological process;
- difficulties in anesthetizing the patient;
- rapid caries progression.

The characteristic opacities are usually limited to the incisal or cuspal one-third of the crown, and rarely involve the cervical one-third. The structure of altered enamel can be divided into two surfaces: surface and subsurface. The intact enamel surface is typically hard, smooth and often hypermineralized following posteruptive maturation. The subsurface enamel is soft and porous and thus less resistant to external factors activity [24]. MIH-affected teeth, particularly FPMs, are often hypersensitive to stimuli and may be difficult to anesthetize. It is believed that there is subclinical pulpal inflammation characteristic for this syndrome [15]. Hygienic neglect is also often the result of the hypersensitivity. Patients avoid tooth-brushing because of severe symptoms during brushing when the bristle is in contact with the surface of the enamel [22, 23, 24].

**Factors potentially responsible for MIH occurrence.** Many long-term randomized studies and meta-analyses clearly indicate that the etiology of occurrence of molar-incisor hypomineralization is multifactorial. Most often it is a combination of systemic and genetic factors [25, 26]. The exogenous risk factors affecting the increase in the prevalence of MIH include, among others, low birth weight, taking antibiotics and potentially toxic drugs prenatally and during breastfeeding. In each case, while trying individually to determine the etiology of the development of the disease

process in the patient, we should be aware that between week 28 of gestation and the first 10 days of initiation of amelogenesis by ameloblasts, the first permanent teeth are formed (FMP- first permament molar). Subsequent teeth are formed later. If the function of ameloblasts is disturbed, also in a cyclic manner, it may lead to the development of hypoplasia or hypomineralization, depending on the stage of tissue formation [27, 28]. In addition to the harmful factors affecting the child *in utero*, there are also a number of other factors acting adversely in the postnatal period; these include, among others, otitis media, pneumonia, asthma, urinary tract inflammation, and chickenpox [29, 30, 31]. These infections primarily affect indirectly by producing hypoxia of the organism, and consequently, disorders of the process of enzymatic changes of ameloblasts [32].

Currently, one of the widely-discussed factors is deficiency of vitamin D as a key factor in the process of enamel development [33]. It has been demonstrated that the effect of vitamin D and its derivatives, by affecting the concentration of calcium and phosphorus in the blood and regulating gene expression, also controls the efficiency of amelogenesis [34, 35, 36].

**MIH case study.** A 23-year-old patient referred to the outpatient university clinic due to atypical pain in the molars, and to have the diagnosis revised. During the medical history taking, the patient reported that the pain had been present with varying intensity for a few years, while attempts at treatment had so far failed to produce the desired therapeutic effect. Finally, during one dental surgery visit, endodontic treatment was proposed, but the patient did not give consent.

Extraoral examination revealed no deviations from generally accepted standards of the stomatognathic system. Intraoral examination found quantitative and qualitative changes in the tissues of teeth 16, 26, 36 and 46, and qualitative changes in the upper incisors. After thorough drying of hard tissue, the upper incisors showed changes in the translucency of the enamel in the form of linear, horizontal, well-demarcated opacity lines. The maxillary incisors did not exhibit the characteristics of hypersensitivity, but the first molars of the upper and lower arches exhibited characteristics of significant sensitivity, particularly to thermal stimuli, mainly cool stimuli. Changes in the colour of the enamel and loss of tissue in the area of hard structure of functional cusps, showed no visible lesions suggestive of a progressive carious process. Defects of enamel tissue showed a colour from gray-brown to dark-yellow, but were always well demarcated from the surrounding tissue.

The patient was also referred to take a dental panoramic radiograph. Based on the examination and differential diagnosis of the patient, the presence of molar-incisor hypomineralization was found, but there was a lack of indications for endodontic treatment. Because of the severe symptoms of hypersensitivity and the patient's dissatisfaction with the aesthetics of the posterior section and extent of the lesions in molars, the patient was proposed an overlay restoration. The planned treatment was also aimed at reconstructing the partially destroyed occlusal zone in the area of teeth 16, 26, 36 and 46. In addition, because of disproportion of bone bases and teeth – crowding of teeth – the patient was planning orthodontic treatment using fixed braces; hence, also due to the orthognathic procedure, comprehensive reconstruction and protection of molars was necessary. Because of the slight aesthetic failure caused by hypomineralization defects in the upper incisors, it was decided, together with the patient, to postpone the proceedings in order to improve the appearance of the teeth by using CPP-ACP (Casein Phosphopetide-Amorphous Calcium Phosphate). The performed treatment was undertaken according to the steps of therapeutic proposal (Tab. 3).

**Table 3.** Therapeutic management of Molar-Incisor Hypomineralization

| Clinical management approach after diagnosing MIH | |
|---|---|
| Steps | Recommended therapeutical procedures |
| Early diagnosis | The earlier the diagnosis, the earlier patient-monitoring.<br>Examine patient's molars on radiograph if possible.<br>Monitor these teeth during eruption |
| Remineralization and desensitization | Apply localized topical fluorides at high concentrations |
| Prevention of dental caries and PEB | Instruction on oral hygiene. Professional cleansing and controls visits. Monitoring of diet: reduction of harmful dietary habits: reduction of the amount of cariogenic food and highly erosivity of diet.<br>Place pit and fissure sealants (preferably glass- ionomers, due to difficulties in bonding of composite sealants with the tooth tissue).<br>Monitoring existing parafunctions (if any). |
| Teeth restorations | During maturation of tooth tissues – materials based on glass-ionomers (biomimetic approach). With large tissue damage – standard crowns<br>When tissues are formed and dimensions of the chamber are reduced – composite materials (avoiding materials based on BPA is worthwhile).<br>With a large destruction of tissues – possibility of prosthetic restoration. |
| Extractions | In the case of irreversible, subgingival tooth tissue loss. |
| Periodic maintenance | Monitoring of altered tissue (due to hypomineralization), fillings and restorations (especially in the area of possible PEB), in the event of failure, consider full coronal coverage restorations in the long-term |

**Treatment.** Due to the presence of severe hypersensitivity symptoms, anticipated difficulties during anesthesia and patient approach to dental treatment, the patient was proposed a treatment consisting of four stages. Each of the teeth affected by disorder was to be treated during a separate visit. Each of the steps was performed under local infiltration – conduction anesthesia with preparations based on articaine. In each case, the mixed infiltration-conduction anesthesia guaranteed the desired effect. Before the first treatment, to minimize the fear of a treatment, the patient took a sedative preparation. Before the procedure, the colour for future restorations was chosen – D2, based on the specifications of the Vita shade. After obtaining a positive response to the anesthesia, there began the preparatory treatment of pathologically altered tissues for overlay restoration. The procedure was performed using a drill with a diamond coating with a low-speed hand piece with water cooling to minimize the traumatic effect of temperature on the living pulp.

**Preparation of tissues.** Preparation consisted in the removal of structurally altered tissues (Fig. 1) and making in the healthy enamel a shelf of the rounded shoulder type (with a rounded radius inside). The treatment was carried out using a magnifying glass. The method of preparation of contact was chosen on the basis of destructive criterion Tsai-Wu on composites, which are anisotropic materials [37].

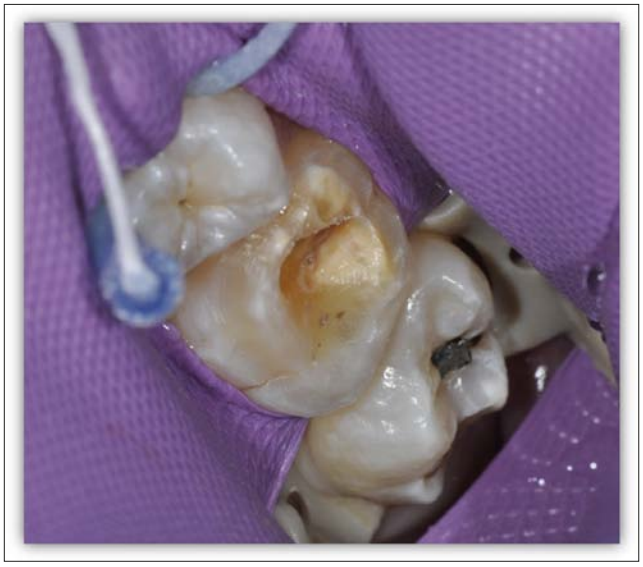

**Figure 1.** Preparation of tissues of tooth 16 with MIH

**Figure 2.** Composite restoration prepared for adhesive cementation

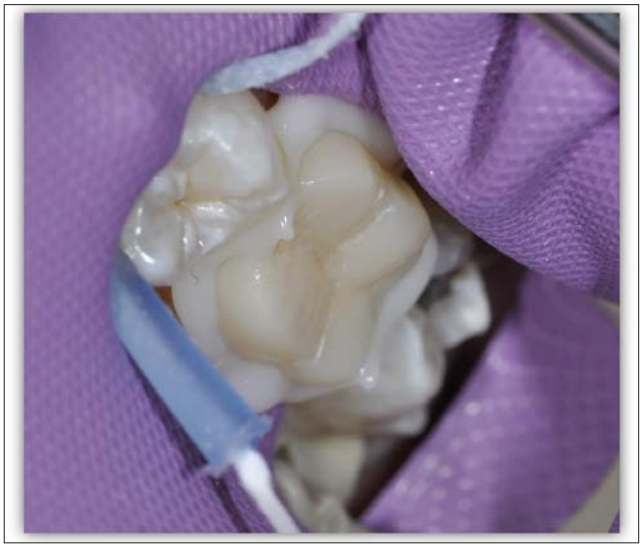

**Figure 3.** Procedure of cementation

**Making impressions.** The prepared tooth tissues were impregnated using fluorine-based compounds. After verifying the location of points of contact and contact between antagonists, protection of the gums was began using retraction cords, and impressions were made. A two-layer one-step working impression was created using silicone type A. The impression of each opposite arch was prepared with alginate of increased resistance to fluctuations in an aqueous medium. Occlusal registration was created with wax. The patient was provided with temporary restorations made with the direct technique using light-cured temporary materials. The obtained parameters and information were submitted to a dental laboratory where overlay restorations were made. Restorations were prepared using the partly-individualized articulator.

**Preparation tissues for adhesive cementation.** At the next visit, the operative field was insulated using a latex-free rubber dam, the temporary restoration was removed, and an attempt to make a final restoration on the trial glycerin paste was made. After thorough cleaning of the prepared tissues, the procedure of enamel etching started which lasted five seconds. The next step was to insert a sterile piece of cotton wool soaked in chlorhexidine solution with a concentration of 2%, to minimize the possible effect of aging of resins by blocking MMP (matrix metalloproteinases), located in the inside-tubular fluid [38, 39]. The tissues prepared in this way were impregnated with the self-etching hydrophilic resin, by precise rubbing for 20 seconds on each tooth surface, and were light-cured for polymerization of the resin.

**Adhesive cementing and restoration of margin between natural tissues, cement and overlay restoration.** Properly prepared, silanized and impregnated restoration in the form of an *overlay* was cemented with resin cement with a dual-type bonding (Fig. 2). Each surface was light-cured on the connection between the restoration and natural tooth tissues, which provided the initial bonding of cement mass while, at the same time, leaving it flexible to have the possibility of atraumatic cutting-off of any excess. The excess was cut off with a scalpel 12, also in the areas of contact separated with flexible wedges (Fig. 3). After a thorough checking of the contact between the restoration and the tooth surfaces, the cement surface was insulated using glycerin paste to inhibit the formation of a disadvantageous, in this case, inhibition layer. Each tooth surface was then light-cured for 20 seconds, which allowed for the final polymerization of the composite.

**Finishing and polishing.** After removing the rubber dam, the correction of centric and eccentric occlusion was made with the articulating film (Fig. 4). The restoration surface was processed with white stones on the accelerating handpiece with water cooling. The final polishing procedure was made with grey rubbers for the composite and polishing discs.

The patient was instructed on the hygienic recommendations and informed about the need for frequent checks.

**Follow-up check.** The patient reported to control visits after completion of procedures after 1, 3, 6 and 12 months. She reported that the pain had disappeared permanently and the aesthetics and functioning of the lateral section was satisfactory. At each visit, fluoridation was carried out after previous procedure of professional tooth cleaning. Clinical examination did not confirm activity of caries in the area of prosthetic restorations.

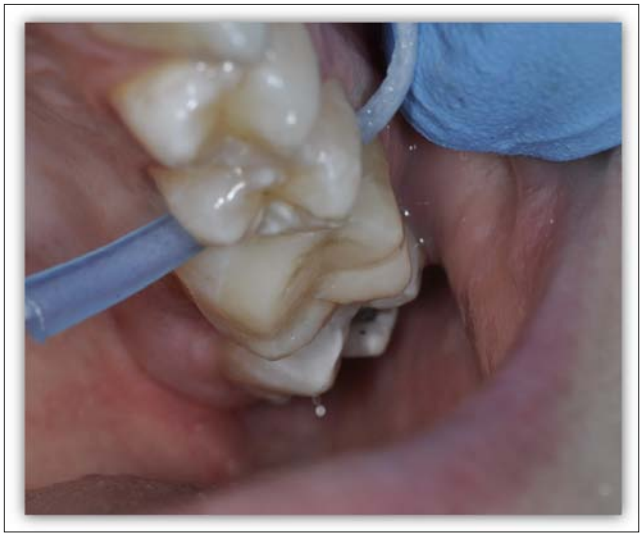

**Figure 4.** Tooth with MIH restored with composite overlay

## CONCLUSIONS

The prevalence of MIH and difficulties in diagnosing the disease make it is necessary to determine the exact diagnostic and therapeutic patterns of management. The preventive procedure should also engage guardians / parents of the children. Due to its pain implications the disease undiagnosed in time, can lead to deep-seated psychological problems, including in this case, dentophobia. The lack of awareness of dentists having no knowledge about the prevalence of MIH, often leads to the drawing erroneous conclusions, and determining therapeutic solutions harmful to the patient, including the extraction of teeth affected by the disease.

## REFERENCES

1. Wright JT, Carrion IA, Morris C. The molecular basis of hereditary enamel defects in humans. J Dent Res. 2015; 94(1): 52–61.
2. Ghanim A, Elfrink M, Weerheijm K, Mariño R, Manton D. A practical method for use in epidemiological studies on enamel hipomineralisation. Eur Arch Paediatr Dent. 2015; 16(3): 235–246.
3. Koch G, Hallonseten AL, Ludvigsson N, Hansson BO, Holst A, Ullbro C. Epidemiologic study of idiopathic enamel hypomineralisation in permament teeth of Swedish children. Community Dent Oral Epidemiol. 1987; 15(5): 279–285.
4. Leppaniemi A, Lukinmaa PL, Alaluusua S. Nonfluoride hipomineralisations in the permament first molars and their impact on the treatment need. Caries Res. 2001; 35(1): 36–40.
5. Soviero V, Haubek D, Trindade C, Da Matta T, Poulsen S. Prevalance and distribution of demarcated opacities and their sequelae in permanent 1st molars and incisors in 7 to 13-year-old Brazilian children. Acta Odontal Scand. 2009; 67(3): 170–175.
6. Fagrell TG, Lingstrom P, Olsson S, Steiniger F, Norén JG. Bacterial invasion of dentine tubules beneath apparently intact but hypomineralized enamel in molar teeth with molar incisor hypomineralization. Int J Paediatr Dent. 2008; 18(5): 333–340.
7. Chawla N, Messer LB, Silva M. Clinical studies on molar-incisor-hypomineralisation part 2: development of a severity index. Eur Arch Paedtr Dent. 2008; 9(4):191–199.
8. Chałas R, Wójcik-Chęcińska I, Woźniak MJ, Grzonka J, Święszkowski W, Kurzydłowski KJ. Dental plaque as a biofilm – a risk in oral cavity and methods to prevent. Postepy Hig Med Dosw (Online). 2015; 69: 1140–1148.
9. Jälevik B: Prevalence and diagnosis of Molar-Incisor hypomineralisation (MIH): a systematic review. Eur Arch Paediatr Dent. 2010; 11(2): 59–64.
10. Jälevik B, Klingberg GA. Dental treatment, dental fear and behaviour management problems in children with severe enamel hypomineralizationof their permanent first molars. Int J Paediatr Dent. 2002; 12(1): 24–32.
11. Kotsanos N, Kaklamanos EG, Arapostathis K. Treatment management of first permanent molars in children with Molar-Incisor Hypomineralisation. Eur J Paediatr Dent. 2005; 6(4): 179–184.
12. Weerheijm KL, Jälevik B, Alaluusua S. Molar-incisor hypomineralisation. Caries Res. 2001; 35(5): 390–391.
13. Cho SY, Ki Y, Chu V. Molar incisor hypomineralization in Hong Kong Chinese children. Int J Paediatr Dent. 2008; 18(5): 348–352.
14. Ogden AR, Pinhasi R, White WJ. Nothing new under the heavens: MIH in the past? Eur Arch Paediatr Dent. 2008; 9(4): 166–171.
15. Whatling R, Fearne JM. Molar incisor hypomineralization: a study of aetiological factors in a group of UK children. Int J Paediatr Dent. 2008; 18(3): 155–162.
16. Van Amerongen WE, Kreulen CM. Cheese molars: a pilot study of the etiology of hypocalcifications in first permanent molars. ASDC J Dent Child. 1995; 62(4): 266–269.
17. Pirard C, Sagot C, Deville M, Dubois N, Charlier C: Urinary levels of bisphenol A, triclosan and 4 nonylphenol in a general Belgian population. Environ Int. 2012; 48: 78–83.
18. Hunt PA, Lawson C, Gieske M, Murdoch B, Smith H, Marre A et al.: Bisphenol A alters early oogenesis and follicle formation in the fetal ovary of the rhesus monkey. Proc Natl Acad Sci U S A. 2012; 109: 17525–17530.
19. Alonso-Magdalena P, Quesada I, Nadal A: Endocrine disruptors in the etiology of type 2 diabetes mellitus. Nat Rev Endocrinol. 2011; 7(6): 346–353.
20. Vom Saal FS, Nagel SC, Coe BL, Angle BM, Taylor JA: The estrogenic endocrine disrupting chemical bisphenol A (BPA) and obesity. Mol Cell Endocrinol. 2012; 354(1–2): 74–84.
21. Weerheijm KL. Molar-incisor-hypomineralisation (MIH). Eur J Paediatr Dent. 2003; 4(3): 114–120.
22. Jälevik B. Enamel hypomineralisation in permanent first molars. A clinical, histo-morphological and biochemical study. Swed Dent J Suppl 2001; 149: 1–86.
23. Fitzpatrick L, O'Connell A. First permanent molars with molar incisor hypomineralisation. J Ir Dent Assoc. 2007; 53(1): 32–37.
24. Wright JT, Carrion IA, Morris C. The molecular basis of hereditary enamel defects in humans. J Dent Res 2015; 94(1): 52–61.
25. Sehic A, Risnes S, Khan QE, Khuu C, Osmundsen H. Gene expression and dental enamel structure in developing mouse incisor. Eur J Oral Sci. 2010; 118(2): 118–130.
26. Simmer JP, Fincham AG. 1995. Molecular mechanisms of dental enamel formation. Crit Rev Oral Biol Med. 1995; 6(2):84–108.
27. Gasse B, Karayigit E, Mathieu E, Jung S, Garret A, Huckert M et al. Homozygous and compound heterozygous MMP20 mutations in amelogenesis imperfecta. J Dent Res. 2013; 92(7): 598–603.
28. Hart PS, Hart TC, Michalec MD, Ryu OH, Simmons D, Hong S,Wright JT. 2004. Mutation in kallikrein 4 causes autosomalrecessive hypomaturation amelogenesis imperfecta. J Med Genet. 41(7): 545–549.
29. Rosli A, Fanconi A. Neonatal hypocalcaemia. "Early type" in low birth weight newborns. Helv Paediatr Acta. 1973; 28(5): 443–457.
30. Hansen AK, Skejby A, Aarhus N, Wisborg K, Uldbjerg N, Henriksen TB. Risk of respiratory morbidity in term infants delivered by elective caesarean section: cohort study. BMJ 2008; 336(7635): 85–87.
31. Beentjes VE, Weerheijm KL, Groen HJ. Factors involved in the aetiology of molar-incisor hypomineralisation (MIH). Eur J Paediatr Dent. 2002; 3(1): 9–13.
32. Norwitz ER, Robinson JN, Challis JR. The control of labor. N Engl J Med. 1999; 341(9): 660–666.
33. Foster BL, Nociti FH Jr, Somerman MJ. 2014. The rachitic tooth. Endocr Rev. 35(1): 1–34.
34. Davideau JL, Lezot F, Kato S, Bailleul-Forestier I, Berdal A. Dental alveolar bone defects related to Vitamin D and calcium status. J Steroid Biochem Mol Biol. 2004; 89–90(1–5): 615–618.
35. Berdal A, Papagerakis P, Hotton D, Bailleul-Forestier I, Davideau JL. Ameloblasts and odontoblasts, target-cells for 1,25-dihydroxyvitamin D3: a review. Int J Dev Biol. 1995; 39(1): 257–262.
36. Papagerakis P, MacDougall M, Hotton MD, Bailleul-Forestier I, Oboeuf M, Berdal A. 2003. Expression of amelogenin in odontoblasts. 2003; Bone. 32(3): 228–240.
37. Dejak B, Mlotkowski A, Romanowicz M. Strength estimation of different designs of ceramic inlays and onlays in molars based on the Tsai-Wu failure criterion. J Prosthet Dent. 2007; 98(2): 89–100.
38. Osorio R, Yamauti M, Osorio E, Ruiz-Requena ME, Pashley D, Tay F, Toledano M. Effect of dentin etching and chlorhexidine application on metalloproteinase-mediated collagen degradation. Eur J Oral Sci. 2011; 119(1): 79–85.
39. Chałas R, Rudzka O. Dentin adhesion and matrix metalloproteinases. Curr Iss Pharm Med Sci. 2013; 26(3): 282–286.