Molar-Incisor Hypomineralization

Adopted
2024

How to Cite: American Academy of Pediatric Dentistry. Molar-incisor hypomineralization. The Reference Manual of Pediatric Dentistry. Chicago, IL: American Academy of Pediatric Dentistry; 2025:465-72.

Abstract

*Molar-incisor hypomineralization (**MIH**) describes a qualitative defect in the enamel of both primary and permanent teeth. Due to inadequate mineralization, teeth affected with MIH are vulnerable to breakdown of tooth structure, caries, sensitivity, tooth loss. and subsequent occlusion problems. This best practice document discusses the clinical presentation, sequelae, prevalence, etiology, classification, diagnosis, and management of MIH. Care pathways for children and adolescents who present with MIH require an understanding of the condition, its severity, and interventions to prevent or manage symptoms, caries, and posteruptive breakdown of tooth structure where possible. Preventive measures, including sealants and fluoride use, are presented along with suggestions for treating hypersensitivity. A discussion of short-term, intermediate, and definitive treatment options is provided. When restorative treatment is not feasible, options for the timing of planned extraction and molar substitution are discussed. Pediatric dentists should familiarize themselves with the diagnosis as well as preventive and restorative options available for children and adolescents who present with MIH in order to optimize their oral health and reduce their care burden over their lifetime.*

This document was developed through a collaborative effort of the American Academy of Pediatric Dentistry Councils on Clinical Affairs and Scientific Affairs to offer updated information and recommendations for dental professionals regarding the management of molar-incisor hypomineralization.

KEYWORDS: MOLAR-INCISOR HYPOMINERALIZATION; MOLAR HYPOMINERALIZATION; HYPOMINERALIZED TEETH; HYPOMINERALIZED SECOND PRIMARY MOLARS; DENTAL DEVELOPMENTAL DEFECTS; CHILD

Purpose

The American Academy of Pediatric Dentistry recognizes the complexity and importance of managing teeth affected with molar-incisor hypomineralization/molar hypomineralization (**MIH**) and the effect of MIH on an individual's well-being. A comprehensive approach for managing teeth affected with hypomineralization is an essential component in the delivery of oral health care for infants, children, and adolescents, including those with special health care needs. This document is intended to aid in the diagnosis of hypomineralization, which includes MIH, hypomineralized second primary molars (**HSPM**) and hypomineralization of other teeth, and to provide recommendations to help practitioners make decisions regarding prevention and comprehensive management of primary and permanent teeth affected by hypomineralization.

Methods

These recommendations were developed utilizing the resources and expertise of the American Academy of Pediatric Dentistry members and an expert consultant operating through the Council on Clinical Affairs. A search was conducted using the database of PubMed/MEDLINE with the parameters: terms: (*molar hypomineralization* OR *molar-incisor hypomineralization* OR *incisor* OR *quality of life* OR *prevalence* OR *dental enamel hypoplasia)* AND (*evidence-based dentistry* OR *dental care for children* OR *pediatric dentistry)*; publication date from January 1, 2013; humans; child: birth-18 years. Four hundred articles met these criteria. Papers for review were chosen from this list and from references within the selected articles. When data did not appear sufficient or were inconclusive, recommendations were based upon expert and/or consensus opinion by experienced researchers and clinicians.

Background

Molar-incisor hypomineralization is a term describing demarcated hypomineralization affecting at least 1 to 4 first permanent molars and often associated with affected permanent incisors.[1] It can also be known as molar hypomineralization which is a term describing hypomineralization in both primary and permanent dentitions.[2] The presence of opacities on a permanent incisor is not mandatory for the diagnosis of MIH.[3(p33)] Historically, developmental defects of enamel (DDE) have been classified into quantitative enamel defects (eg, enamel hypoplasia) and qualitative enamel defects (eg, diffuse opacities as enamel fluorosis, demarcated opacities)[4] which are characteristic of the defects seen in MIH. Similar defects have been described in affected second

ABBREVIATIONS

EAPD: European Academy of Pediatric Dentistry. **GIC:** Glass ionomer cement. **HSPM:** Hypomineralized second primary molars. **mDDE:** Modified Developmental Defect of Enamel index. **MIH:** Molar-incisor hypomineralization/molar hypomineralization. **PEB:** Posteruptive breakdown. **SDF:** Silver diammine fluoride. **SSC:** Stainless steel crowns.

primary molars.[5] The terms HSPM[6] and deciduous molar hypomineralization (DMH)[5] have been used concurrently to describe these demarcated hypomineralization defects of 1 to 4 primary second molars. Children with HSPM have 10 times greater probability of having MIH than children without HSPM.[7-10] Similarly, hypomineralization of other permanent teeth (HOPT) has been proposed to describe affected permanent teeth other than the index teeth (eg, canines, premolars, second molars) with an increased probablilty in children with MIH compared to children without MIH.[11,12]

The hypomineralization defects vary from small well-demarcated areas of color change to involvement of the entire crown with a normal thickness of enamel.[13(p131)] They are distributed in an asymmetrical fashion and have well-defined and discrete borders that distinguish them from the diffuse symmetrical opacities of enamel fluorosis.[1,10] Severity ranges widely from distinct isolated white, yellow, or brown opacities to severe posteruptive breakdown (**PEB**) of tooth structure.[1,3(pp34,35),10,14] PEB, a characteristic feature related to severe enamel hypomineralization, can occur immediately after eruption as a result of masticatory forces and can be mistaken for enamel hypoplasia.[10] Hypoplastic enamel, a primary quantitative developmental defect, is differentiated from PEB by having smooth enamel borders with thin, pitted, and deficient enamel across the tooth surface.[3(pp33-35),10] The margins of the defects seen in MIH with PEB are sharp and irregular due to posteruptive shearing of weakened enamel.[15] The extent of coloration of the defects reflects their degree of subsurface porosity and mineral density values, which are correlated with their liability to surface disintegration after eruption.[16] The yellow-brown defects typically extend through the entire enamel thickness, and are more porous and more prone to PEB than the white-cream-colored opacities.[16]

These developmental, qualitative enamel defects are caused by reduced mineralization, increased protein and water content, and inorganic enamel components which can lead to discoloration, increased sensitivity, and fractures of the affected teeth.[13(p131),17] The affected teeth also are prone to dental caries, atypical caries, wear, and breakdown.[18] The risk of developing caries in affected teeth is up to 4.6 times higher than in teeth without MIH.[19] Exposure to masticatory forces increases the risk for enamel breakdown, which is more common in molars compared to incisors.[20] Another frequent finding in teeth with MIH is increased sensitivity to a current of air and thermal (ie, cold, warm) and mechanical (eg toothbrushing) stimuli.[1,10] Permeation of bacteria through the porous, hypomineralized enamel—and subsequent subclinical pulpal inflammation[21]—and the anomalous pulpal innervation density of affected teeth have been implicated.[22] Severity of hypersensitivity is significantly higher in teeth with structural disintegration immediately after tooth eruption.[23]

The prevalence of MIH varies widely between 3% to 44% and 0.5% to 40% depending on the study and country.[14,24-26] Epidemiological cohorts from the US remain limited, yet the reported US MIH prevalence estimates (10% to 13%)[27,28] do not differ from the reported global MIH prevalence of 13.1% (11.8% to 14.5%)[25]. Meta-analysis of pooled MIH prevalence (116 studies) showed a global prevalence of 13.5%.[29] The prevalence between genders is similar.[25,26]

Etiology and risk factors

MIH is recognized globally as a condition with a complex etiology that may be the result of gene-environmental interactions.[11] While the exact etiology of MIH is unknown, systemic, genetic, and/or epigenetic components are associated with MIH.[11,24,30] These MIH-associated environmental factors occur during the times of early tooth development including prenatal and childhood exposures.[31-34] Suggested predisposing factors include: maternal illness during prenancy,[13(p132),32] premature birth,[13(p132),32] low birth weight,[13(p132),32,34] prenatal exposure to lead,[34] infant illness,[13(p132),32] high fever,[32] use of antibiotics,[13(p132),30,32] infantile eczema,[24] high and low levels of vitamin D at birth,[24] in vitro fertilization,[24] maternal smoking,[24] and acute and chronic childhood illness[36,37] (eg, otitis media, infection). Individuals with cleft lip/palate have a markedly greater prevalence than the general population.[38] Findings in family history and twin studies suggest a genetic association[24,39,40] in combination with environmental risk factors[41]; however, further studies are still required.

Diagnosis and classification of severity

Diagnosis of MIH depends on clinical assessment of the qualitative defects and can be classified as mild, moderate, or severe. To date, there is no unifying global index for MIH; however, several types of indices are reported in the literature. The earliest severity index was used to designate the condition of hypomineralized first permanent molars, which scored the hypomineralized molar defects as mild (limited to altered translucency of enamel), moderate (loss of enamel is apparent), or severe (loss of enamel is associated with affected dentin or atypical restorations are present), although at that time, the term MIH was not yet proposed in the literature.[29] The modified Developmental Defect of Enamel (**mDDE**) index proposed by the Fédération Dentaire Internationale in 1992 incorporated all types of enamel defects[4] including qualitative (eg, demarcated opacities, diffuse opacities) as well as quantitative (eg, hypoplasia) defects, but it did not account for the PEB[18]. Another severity index of MIH looked at the subjective presentation of hypersensitivity, using 2 objective criteria (ie, extent of hypomineralization and number of restorations placed/replaced in each molar) and 1 subjective criterion (ie, tooth sensitivity as reported by the child patient).[42] The Würzburg concept[43] developed a classification index, the MIH Treatment Need Index (MIH-TNI), which looked at the defect, sensitivity, and treatment needs of affected teeth.[44] Lastly, the European Academy of Pediatric Dentistry (**EAPD**) created an index which delineated the severity of the defects as mild (demarcated enamel opacities, no enamel breakdown, provoked sensitivity to external stimuli [air/water but not brushing], mild discoloration of the incisors) versus severe

(demarcated enamel opacities associated with breakdown and caries, spontaneous and persistent hypersensitivity affecting function [eg, brushing, mastication], and strong esthetic concerns that may have psychosocial impact).[14,18,45] A charting method subsequently was created to integrate elements of both the EAPD criteria and the mDDE index for grading the clinical status of MIH and its extent on the involved tooth surface.[15] The mDDE index and the EAPD diagnostic criteria are diagnostic indices commonly used in MIH studies.

Management

Early diagnosis allows provision of preventive or early restorative intervention in order to avoid dental caries, PEB of affected areas, pulpal inflammation, and hypersensitivity and to address cosmetic and psychosocial concerns.[36,37,46] Identifying risk factors, optimizing oral hygiene, providing dietary counseling, controlling sensitivity, promoting remineralization, and discussing treatment options and outcomes as soon as the affected teeth erupt help reduce risk of caries, PEB, and early extraction of unrestorable affected teeth.[2,37,47(p106)] Affected teeth with marked hypersensitivity present a challenge for the establishment of proper oral hygiene, leading to increased caries risk.[19,23] They also are reported as being difficult to anesthetize,[36,37] which can make restorative treatment challenging[48] and have a significant impact on a child's oral health-related quality of life.[49] This can lead to children developing dental fear, anxiety, and dental fatigue due to the burden of care of multiple treatment visits.[50]

The management and treatment approaches for affected teeth are predicated on the severity of the defect and clinical phenotype. Mild cases typically are managed with minor modification of traditional therapeutic modalities such as the use of remineralizing agents, silver diammine fluoride (**SDF**), and sealants.[14,44,51] Moderately and severely affected molars often require management for dental hypersensitivity coupled with restorative approaches or extraction.[13(p134)] Restorations in affected teeth are associated with poorer long-term outcomes and higher cost of treatment compared to the healthy cohort.[46,52,53] Treatment can be complex, involving short-, medium- and long-term treatment strategies.[14,36,46,47(p106),53] Treatment under general anesthesia often is indicated due to hypersensitivity, difficulty with anesthetizing multiple teeth, dental anxiety, and the complexity of restorative and/or surgical care.[14,52-54]

The goals are to prevent hypersensitivity, PEB, and development of dental caries and to improve esthetics in the affected teeth.[13(p134),37] The use of fluorides (eg toothpaste, mouthwash, varnish, SDF) and agents that promote remineralization and the use of resin infiltration to promote structural integrity have been shown to be effective in prevention of PEB in mild cases.[55,56] The use of SDF for prevention and pretreatment also has been effective in reducing sensitivity.[44,51] While desensitizing toothpastes and agents such as casein phosphopeptide-amorphous calcium phosphate (CPP-ACP) have been suggested to manage sensitivity[53], studies have shown limited effectiveness.[36] Early treatment to manage hypersensitivity in newly erupted molars (with or without enamel loss) can be accomplished using SDF, glass ionomer sealants, fissure sealants, and restorations that do not require excessive etching, rinsing, and drying—which may cause hypersensitivity and subsequent patient discomfort.[51] Conventional fissure sealants may fail due to the decreased bond strength in affected enamel.[57] When fissure sealants are indicated, pretreatment with 5% sodium hypochlorite to remove the protein and organic layer,[58] in addition to the use of a bonding agent prior to placement the sealant,[59] may improve bond strength.

Restorative treatment

Clinical management of affected incisors often is influenced by the patient (or parent) due to concerns with esthetics rather than function.[36] Minimally invasive techniques may help improve appearance while preserving tooth structure. Management options can include microabrasion, bleaching, resin infiltration, direct/indirect composite restorations, or veneers.[36] The use of resin infiltration has been shown to decrease risk of enamel breakdown and maintain structural integrity of both affected incisors and molars.[55]

The severity, extent of PEB, caries involvement, hypersensitivity, and patient compliance influence the choice of restoration of hypomineralized molars.[36] Bonding to dentin in composite restorations is not compromised in affected teeth; however, there is no microretentive etch pattern with affected enamel.[43,57] In order to improve microadhesion to the weakened enamel, removing 1.5 mL of enamel, placing margins in non-affected areas, and using adhesive stabilization with a dentin bonding agent have been recommended.[43,57] Beveling margins to sound enamel also has been suggested.[56] Glass ionomer cement (**GIC**) can be used as dentin replacement[43] or as interim restorations.[44,53] Recently, glass hybrid and reinforced composite restorations used to treat severe MIH showed a survival of 77% and 93% respectively at 24 months; however, this decreased over time.[60]

In many cases, the use of preformed metal crowns or stainless steel crowns (**SSC**) to restore affected primary and permanent molars may be indicated to prevent tooth loss, control sensitivity, and establish correct interproximal and proper occlusal contacts.[37,43] GIC can be used to reinforce the SSC.[53] Prefabricated zirconia crowns can be used when esthetics are a consideration.[61] Hall-technique crowns can be used for HSPM[62], however, there is no research regarding use in affected permanent first molars.[14,63] In some cases, the use of orthodontic separators can create space and diminish the need for excessive interproximal tooth reduction.[43] An orthodontic band and GIC may be used as an interim alternative to help reduce preparation of tooth structure and support the weakened enamel.[56] Long term restorations in adulthood can include an onlay, overlay, indirect (computer-aided design/computer-aided manufacturing [CAD-CAM]) ceramic restorations or lab-fabricated crown.[64]

Extraction/molar substitution

Interceptive extraction of affected first permanent molars with a poor long-term prognosis is an option to decrease the burden of care, and timing of the extraction is critical to treatment success.[13(p138),47(pp106,107),65-67] Molar substitution is ideal when the bifurcation of the second permanent molar is mineralizing and if there are third molars developing.[37,47(p110),67] When extraction of the mandibular first permanent molar is carried out at the ideal time of development of the second permanent molar (between the age of 8 and 10 years), there is a good probability (50-59%) of spontaneous eruption of the second permanent molar into the first molar position.[66-68] Maxillary second permanent molars erupt in the proper position following the extraction of the first molar more consistently.[65-67]

Considering the long-term ramifications of early molar loss is beneficial when planning for extractions. In cases of excessive arch space, orthodontic treatment may be required to close spaces.[47(pp108,109)] A midline shift, over-eruption of the opposing molar, and occlusal interference may occur if molars are extracted in only 1 quadrant.[47(pp108,109)] If mandibular first permanent molars are extracted too early, the potential for distal drifting and rotation of the second premolars exists.[47(p109)] Because of the thin lingual plate, the second permanent molar can tilt mesiolingually resulting in nonworking interferences or a reverse crossbite in the nonworking side.[47(pp108,109)] This can lead to excessive wear of teeth due to malocclusion and food impaction at the site of the mesially-inclined molar.[47(pp108,109)] Also, the early extraction of the first permanent molars can result in increased overbite and retroinclination of lower incisors.[47(p110)] Orthodontic consultation may help some parents make an informed decision about extractions, especially in children with decreased facial height, crowded lower incisors, or deep overbite.[47(p110)] If the first permanent molar is extracted following the eruption of the second molar, the second molar will not spontaneously migrate mesially,[65] and orthodontics will be required to close spaces.

Compensating extraction of sound maxillary first permanent molars has been suggested for patients requiring interceptive extraction of mandibular first molars to prevent supraeruption of the unopposed molar.[65] Supraeruption interferes with the proper eruption of the second permanent molar and space closure and contributes to other occlusal interferences.[65,67] Evidence suggests a small risk of these complications from supraeruption of the maxillary first permanent molar and the decision to perform compensating extractions be made on a case by case basis.[65,67] Current evidence also recommends against routine balancing extractions of sound molars in the arch to maintain arch symmetry and to prevent a midline shift.[65,67]

Orthodontic treatment may be needed to refine the alignment and occlusion; a multidisciplinary approach may be beneficial when deciding to extract affected first permanent molars.[65,67] An orthodontic assessment prior to planning for extractions is beneficial in cases of Class II malocclusion with maxillary protrusion, lower lip trap, and increased overjet, bimaxillary protrusion, severe crowding, Class III malocclusion, maxillary constriction, and a skeletal anterior open bite.[47(pp106-109)]

Factors that would support the decision to extract include[65,67]

1. severely compromised affected molars (eg, deep-caries, pulpal or periapical pathology, progressing PEB).
2. a full complement of permanent teeth including third molars.
3. dental crowding, which would require extraction of healthy teeth for orthodontics.
4. hypersensitive or painful teeth.
5. history of irregular or symptomatic appointments.
6. dental anxiety or poor patient cooperation for multiple restorative procedures.
7. financial burden of care.

Factors that would support maintenance of the first permanent molar include[47] hypodontia, a spaced dentition, need for anchorage in severe malocclusion cases.

Periodic reevalutation

Patients at increased risk for MIH benefit from frequent (every 3 to 6 months) periodic evaluations to receive anticipatory guidance, to identify affected teeth as early as possible, and to implement preventive measures as soon as affected teeth erupt. Because of the high rate of failure of restorations in hypomineralized teeth, patients also require frequent periodic evaluations to avoid secondary caries, more extensive breakdown, and repeat treatment.[14,46,53]

Recommendations

Hypomineralization in the primary and permanent dentition can have a substantial impact on children, adolescents, and individuals with special health care needs. Hypomineralization can affect tooth sensitivity and structural stability, caries risk, occlusion, esthetics, and psychosocial concerns. Patients with hypomineralization require a comprehensive treatment approach including preventive and therapeutic interventions to avoid caries, extensive breakdown of tooth structure, tooth loss, psychosocial concerns, and an increase in burden of care as well as a decrease in oral health-related quality of life. In order to protect and preserve tooth structure, prevent or control hypersensitivity, and promote a stable and functional occlusion and esthetically-pleasing dentition, practitioners should

- identify affected teeth and determine the severity of the defects early.
- identify risk factors and provide patient education, dietary counseling, and guidance.
- develop short-, intermediate-, and long-term treatment plans to include
  - individualized in-office and at-home preventive regimens;
  - remineralization/desensitization strategies to decrease sensitivity;
  - control of pain and anxiety due to tooth hypersensitivity and burden of care;
  - management of the developing occlusion;

Table. MANAGEMENT STRATEGIES OF MIH

Severity	Diagnosis	Prevention			Restorative treatment			
		Home care	Control of sensitivity	Professional recommendations	Short-term	Medium-term	Long-term (definitive treatment)	
					Molars	Molars	Permanent molars**	Incisors
Mild	Demarcated or isolated opacities in nonstress bearing areas. No caries. Normal sensitivity.	Twice daily brushing with fluoridated toothpaste. Drink optimally-fluoridated water (alternatively, take fluoride supplements if fluoride-deficient water supplies).	Fluoride varnish. Silver diammine fluoride.	Identify risk factors. Dietary counseling. Periodic review and professional topical treatment every 6 months. Pit and fissure sealants.	Pit and fissure sealants.	Replacement of pit and fissure sealants.	Pit and fissure sealants.	No treatment. Resin infiltration.
Moderate	Demarcated opacities. No initial PEB. Atypical restorations. Limited caries or PEB without cuspal involvement. Normal to mild dental sensitivity.	Twice daily brushing with fluoridated toothpaste. Drink optimally-fluoridated water (alternatively, take fluoride supplements if fluoride-deficient water supplies).	Fluoride varnish. Silver diammine fluoride.	Identify risk factors. Dietary counseling. Periodic review and professional topical treatment every 6 months. Pit and fissure sealants.	Defective enamel should be removed and restored with glass ionomer cement, resin modified glass ionomer cements.	Composite restoration.	Composite restoration.	Microabrasion. Bleaching. Resin infiltration. Composite restoration.
Severe	Rapid PEB. Widespread caries. Dental sensitivity. Esthetic concerns.	Twice daily brushing with fluoridated toothpaste. Drink optimally-fluoridated water (alternatively, take fluoride supplements if fluoride-deficient water supplies).	5000 ppm fluoride toothpaste. Fluoride varnish. Silver diammine fluoride.	Identify risk factors. Dietary counseling. Periodic review and professional topical treatment every 3 to 6 months. Pit and fissure sealants.	Defective enamel should be removed and restored with glass ionomer cement, resin modified glass ionomer cements. Intracoronal restoration reinforced with orthodontic band	Glass ionomer cement. SSC*.	Orthodontics. Extraction/molar substitution. Ceramic onlays. CAD/CAM. Tooth colored or metal overlay. Crowns (eg SSC, PFM, zirconia).	Microabrasion. Bleaching. Resin infiltration. Composite restoration. Veneers.

Abbreviations in table: CAD/CAM: Computer-aided design/computer-aided manufacturing; MIH: Molar-incisor hypomineralization/molar hypomineralization; PEB: posteruptive breakdown; PFM: Porcelain fused to metal; SSC: Stainless steel crown.

* In cases of severe MIH, pulp therapy may be indicated.

** For primary molars, options include preformed crowns or extraction with consideration given to space maintenance.

  - restorative intervention, when indicated, for PEB and/or caries developmen; and
  - periodic reviews every 3 to 6 months; and
- consider consultation with or referral to specialists (eg, pediatric dentists, orthodontists) for a multidisciplinary approach, especially in severe cases and when considering extraction/molar substitution.

Table provides greater detail for recommendations based on the severity of MIH.

References

1. Weerheijm KL, Jälevik B, Alaws UA. Molar-incisor hypomineralization. Caries Res 2001;35(5):390-1.
2. D3 Group. What is molar hypomin? Available at: "https://www.thed3group.org/what-is-molar-hypomin.html". Accessed: March 17, 2024.
3. Weerheijm KL, Elfrink MEC, Kilpatrick N. Molar incisor hypomineralization and hypomineralized second primary molars: Diagnosis, prevalence and etiology. In: Drummond BK, Kilpatrick N, eds. Planning and Care for Children and Adolescents with Dental Enamel Defects: Etiology, Research and Contemporary Management. Berlin, Heidelberg: Springer-Verlag; 2015:31-44.

References continued on the next page.

4. Clarkson J. Review of terminology, classifications, and indices of developmental defects of enamel. Adv Dent Res 1989;3(2):104-9.
5. Elfrink ME, Schuller AA, Weerheijm KL, Veerkamp JS. Hypomineralized second primary molars: Prevalence data in Dutch 5-year-olds. Caries Res 2008;42(4):282-5.
6. Ghanim A, Manton D, Mariño R, Morgan M, Bailey D. Prevalence of demarcated hypomineralisation defects in second primary molars in Iraqi children. Int J Paediatr Dent 2013;23(1):48-55.
7. Elfrink MEC, Schuller AA, Veerkamp JSJ, Poorterman JHG, Moll HA, ten Cate BJM. Factors increasing the caries risk of second primary molars in 5-year-old Dutch children. Int J Paediatr Dent 2010;20(2):151-7.
8. Elfrink MEC, ten Cate BJM, Jaddoe VWV, Hofman A, Moll HA, Veerkamp JSJ. Deciduous molar hypomineralization and molar incisor hypomineralization. J Dent Res 2012;91(6):551-5.
9. Negre-Barber A, Montiel-Company JM, Boronat-Catalá M, Catalá-Pizarro M, Almerich-Silla JM. Hypomineralized second primary molars as predictor of molar incisor hypomineralization. Sci Rep 2016;6:31929. Available at: "https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4997253/". Accessed May 22, 2024.
10. Weerheijm KL. Molar incisor hypomineralisation (MIH). Eur J Paediatr Dent 2003;4(3):114-20.
11. Bussaneli DG, Vieira AR, Santos-Pinto L, Restrepo M. Molar-incisor hypomineralisation: An updated view for aetiology 20 years later. Eur Arch Paediatr Dent 2022;23 (1):193-8.
12. Kevrekidou A, Kosma I, Kotsanos I, Arapostathis KN, Kotsanos N. Enamel opacities in all other than Molar Incisor Hypomineralisation index teeth of adolescents. Int J Paediatr Dent 2021;31(2):270-7.
13. Wright JT. Diagnosis and management of molar incisor hypomineralisation. In: Soxman JA, ed. Handbook of Clinical Techniques in Pediatric Dentistry, 2nd ed. Hoboken, NJ: Wiley-Blackwell, John Wiley & Sons, Inc.; 2022:131-41.
14. Lygidakis NA, Garot E, Somani C, Taylor GD, Rouas P, Wong FSL. Best clinical practice guidance for clinicians dealing with children presenting with molar-incisor-hypomineralisation (MIH): An updated European Academy of Paediatric Dentistry policy document. Eur Arch Paediat Dent 2022;23(1):3-21. Available at: "https://doi.org/10.1007/s40368-021-00668-5". Accessed May 22, 2024.
15. Ghanim A, Elfrink M, Weerheijm K, Marino R, Manton D. A practical method for use in epidemiological studies on enamel hypomineralisation. Eur Arch Paediatr Dent 2015;16(3):235-46.
16. Farah R, Drummond B, Swain M, Williams S. Linking the clinical presentation of molar-incisor hypomineralisation to its mineral density. Int J Paediatr Dent 2010;20 (5):353-60.
17. Weerheijm KL, Duggal M, Mejàre I, et al. Judgement criteria for molar incisor hypomineralisation (MIH) in epidemiologic studies: A summary of the European Meeting on MIH held in Athens, 2003. Eur J Paediatr Dent 2003;4(3):110-3.
18. Jälevik B. Prevalence and diagnosis of molar-incisor-hypomineralisation (MIH): A systematic review. Eur Arch Paediatr Dent 2010;11(2):59-64.
19. Americano GC, Jacobsen PE, Soviero VM, Haubek D. A systematic review on the association between molar incisor hypomineralization and dental caries. Int J Paediatr Dent 2016;27(1):11-21.
20. Weerheijm KL. Molar incisor hypomineralization (MIH): Clinical presentation, aetiology and management. Dent Update 2004;31(1):9-12.
21. Fagrell TG, Lingström P, Olsson S, Steiniger F, Norén JG. Bacterial invasion of dentinal tubules beneath apparently intact but hypomineralized enamel in molar teeth with molar incisor hypomineralization. Int J Paediatr Dent 2008;18(5):333-40.
22. Rodd HD, Boissonade FM, Day PF. Pulpal status of hypomineralized permanent molars. Pediatr Dent 2007; 29(6):514-20.
23. Linner T, Khazaei Y, Bücher K, Pfisterer J, Hickel R, Kühnisch J. Hypersensitivity in teeth affected by molar-incisor hypomineralization (MIH). Sci Rep 2021;11(1): 17922.
24. Silva MJ, Kilpatrick NM, Craig JM, et al. Etiology of hypomineralised second primary molars: A prospective twin study. J Dent Res 2019;98(1):77-83.
25. Schwendicke F, Elhennawy K, Reda S, Bekes K, Manton DJ, Krois J. Global burden of molar incisor hypomineralization. J Dent 2018;68:10-8. Corrigendum J Dent 2019;80:89-92.
26. Zhao D, Dong B, Yu D, Ren Q, Sun Y. The prevalence of molar incisor hypomineralization: Evidence from 70 studies. Int J Paediatr Dent 2018;28(2):170-9.
27. Davenport M, Welles AD, Angelopoulou MV, et al. Prevalence of molar-incisor hypomineralization in Milwaukee, WI, USA: A pilot study. Clin Cosmet Investig Dent 2019;11:109-17.
28. Tagelsir Ahmed A, Soto-Rojas AE, Dean JA, Eckert GJ, Martinez-Mier EA. Prevalence of molar-incisor hypomineralization and other enamel defects and associated sociodemographic determinants in Indiana. J Am Dent Assoc 2020;151(7):491-501.
29. Lopes LB, Machado V, Mascarenhas P, Mendes JJ, Botelho J. The prevalence of molar-incisor hypomineralization: A systematic review and meta-analysis. Sci Rep 2021;11 (1):22405.
30. Alaluusua S. Aetiology of molar-incisor hypomineralisation: A systematic review. Eur Arch Paediatr Dent 2010; 11(2):53-8.

31. Fatturi AL, Wambier LM, Chibinski AC, et al. A systematic review and meta-analysis of systemic exposure associated with molar incisor hypomineralization. Community Dent Oral Epidemiol 2019;47(5):407-15.
32. Juárez-López MLA, Salazar-Treto LV, Hernández-Monjaraz B, Molina-Frechero N. Etiological factors of molar incisor hypomineralization: A systematic review and meta-analysis. Dent J (Basel) 2023;11(5):111.
33. Wright JT. Enamel phenotypes: Genetic and environmental determinants. Genes (Basel) 2023;14(3):545.
34. Wu X, Wang J, Li YH, Yang ZY, Zhou Z. 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):1700-8.
35. Ahmed AT, Hector EC, Urena-Cirett JL, et al. Early lead exposure associated with molar hypomineralization. Pediatr Dent 2023;45(5):427-33.
36. Rodd HD, Graham A, Tajmehr N, Timms L, Hasmun N. Molar incisor hypomineralisation: Current knowledge and practice. Int Dent J 2021;71(4):285-91.
37. William V, Messer LB, Burrow MF. Molar incisor hypomineralization: Review and recommendations for clinical management. Pediatr Dent 2006;28(3):224-32.
38. Wanderley Lacerda RH, Filgueiras VM, Guedes Mendonça AC, Vieira AR. Molar-incisor hypomineralization in a cohort of individuals born with cleft lip and palate. Orthod Craniofac Res 2024;27(Suppl 1):21-6.
39. Kuhnisch J, Thiering E, Heitmuller D, et al. Genome-wide association study (GWAS) for molar-incisor hypomineralization (MIH). Clin Oral Investig 2014;18(2): 677-82.
40. Teixeira R, Andrade NS, Queiroz LCC, et al. Exploring the association between genetic and environmental factors and molar incisor hypomineralization: Evidence from a twin study. Int J Paediatr Dent 2018;28(2):198-206.
41. Vieira AR. On the genetics contribution to molar incisor hypomineralization. Int J Paediatr Dent 2019;29(1):2-3.
42. Chawla N, Messer L, Silva M. Clinical studies on molar-incisor-hypomineralisation part 2: Development of a severity index. Eur Arch Paediatr Dent 2008;9(4):191-9.
43. Steffen R, Kramer N, Bekes K. The Würzburg MIH concept: The MIH treatment need index (MIH TNI): A new index to assess and plan treatment in patients with molar incisor hypomineralisation (MIH). Eur Arch Paediatr Dent 2017;18(5):355-61.
44. Bekes K, Steffen R, Krämer N. Update of the molar incisor hypomineralization: Würzburg concept. Eur Arch Paediatr Dent 2023;24(6):807-13.
45. Lygidakis NA, Wong F, Jälevik B, Vierrou AM, Alaluusua S, Espelid I. 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(2):75-81.
46. International Association of Paediatric Dentistry. Foundational Articles and Consensus Recommendations: Management of Molar Incisor Hypomineralization, 2020. Available at: "https://iapdworld.org/wp-content/uploads/2020/04/07_Management-of-Molar-Incisor-Hypomineralization.pdf ". Accessed June 23, 2024.
47. Drummond BK, Harding W. Examination and treatment planning for hypomineralized and/or hypoplastic teeth. In: Drummond BK, Kilpatrick N, eds. Planning and Care for Children and Adolescents with Dental Enamel Defects: Etiology, Research and Contemporary Management. Berlin, Heidelberg: Springer-Verlag; 2015:99-112.
48. Ridell K, Borgström M, Lager E, Magnusson G, Brogårdh-Roth S, Matsson L. Oral health-related quality-of-life in Swedish children before and after dental treatment under general anesthesia. Acta Odontol Scand 2015;73(1):1-7.
49. Gutiérrez TV, Ortega CCB, Pérez NP, Pérez AG. Impact of molar incisor hypomineralization on oral health-related quality of life in Mexican school children. J Clin Pediatr Dent 2019;43(5):324-30.
50. Jälevik B, Klingberg GA. Dental treatment, dental fear and behaviour management problems in children with severe enamel hypomineralization of their permanent first molars. Int J Paediatr Dent 2002;12(1):24-32.
51. Ballikaya E, Ünverdi GE, Cehreli ZC. Management of initial carious lesions of hypomineralized molars (MIH) with silver diamine fluoride or silver-modified atraumatic restorative treatment (SMART): 1-year results of a prospective, randomized clinical trial. Clin Oral Investig 2022;26(2):2197-205.
52. Elhennawy K, Jost-Brinkmanna PG, Manton DJ, Paris S, Schwendicke F. Managing molars with severe molar-incisor hypomineralization: A cost-effectiveness analysis within German healthcare. J Dent 2017;63:65-71.
53. Elhennawy K, Schwendicke F. Managing molar-incisor hypomineralization: A systematic review. J Dent 2016;55: 16-24.
54. Raposo F, de Carvalho Rodrigues AC, Lia ÉN, Leal SC. Prevalence of hypersensitivity in teeth affected by molar-incisor hypomineralization (MIH). Caries Res 2019;53 (4):424-30.
55. Nogueira VKC, Soares IPM, Fragelli CMB, et al. Structural integrity of MIH-affected teeth after treatment with fluoride varnish or resin infiltration: An 18-month randomized clinical trial. J Dent 2021;105:103570.
56. Bekes K, Heinzelmann K, Lettner S, Schaller HG. Efficacy of desensitizing products containing 8% arginine and calcium carbonate for hypersensitivity relief in MIH-affected molars: An 8-week clinical study. Clin Oral Investig 2017;21(7):2311-7.
57. Krämer N, Bui Khac NN, Lücker S, Stachniss V, Frankenberger R. Bonding strategies for MIH-affected enamel and dentin. Dent Mater 2018;34(2):331-40.

References continued on the next page.

58. Bayrak GD, Gurdogan-Guler EB, Yildirim Y, Ozturk D, Selvi-Kuvvetli S. Assessment of shear bond strength and microleakage of fissure sealant following enamel deproteinization: An in vitro study. J Clin Exp Dent 2020; 12(3):e220-e226. Available at: "https://www.ncbi.nlm.nih.gov/pmc/articles/PMC7071532/". Accessed July 6, 2024.
59. Lagarde M, Vennat E, Attal JP, Dursun E. Strategies to optimize bonding of adhesive materials to molar-incisor hypomineralization-affected enamel: A systematic review. Int J Paediatr Dent 2020;30(4):405-20.
60. Kaya R, Yavuz BS, Dokumacigil NK, Kargul B. A randomized clinical trial of short fiber reinforced composite and glass hybrid restoration for molars affected by molar hypomineralization. Pediatr Dent 2023;45(4):292-300.
61. Casián-Adem J, Cobos L, Waggoner WF, Fuks AB. Prefabricated zirconia crowns – A solution to treat hypomineralized permanent molars: Report of a case. J Clin Pediatr Dent 2021;45(1):8-11.
62. Declerck D, Mampay E. Non-invasive treatment approach for hypomineralised second primary molars using preformed metal crowns: Results after 1-year follow-up. Eur Arch Paediatr Dent 2021;22(3):479-90.
63. Boyd DH, Thomson WM, Leon de la Barra S, et al. A primary care randomized controlled trial of Hall and conventional restorative techniques. JDR Clin Trans Res 2021;6(2):205-12.
64. Linner T, Khazaei Y, Bücher K, Pfisterer J, Hickel R, Kühnisch J. Comparison of four different treatment strategies in teeth with molar-incisor hypomineralization-related enamel breakdown–A retrospective cohort study. Int J Paediatr Dent 2020;30(5):597-606.
65. Noar J, Taylor G, Ashley P, Williams A, Harrison M, Cobourne MT. A guideline for the extraction of first permanent molars in children (An update of the 2014 guidelines). Faculty of Dental Surgery: The Royal College of Surgeons of England. London, UK; 2023:1-8. Available at: "https://www.rcseng.ac.uk/dental-faculties/fds/publications-guidelines/clinical-guidelines/". Accessed March 15, 2024.
66. Eichenberger M, Erb J, Zwahlen M, Schatzle M. The timing of extraction of non-restorable first permanent molars: A systematic review. Eur J Paediatr Dent 2015;16 (4):272-8.
67. Lakhani S, Noble F, Rodd H & Cobourne MT. Management of children with poor prognosis first permanent molars: An interdisciplinary approach is the key. Br Dent J 2023;234(10):731-6.
68. Patel S, Ashley P. Noar J. Radiographic prognostic factors determining spontaneous space closure after loss of the permanent first molar. Am J Orthod Dentofacial Orthop 2017;151(4):718-26.