Quantifying molar hypomineralization using non-invasive spectrophotometry approaches

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Background

Molar incisor hypomineralization (MIH) describes demarcated defects of enamel that occur prior to the eruption of permanent molars[1]. Enamel of MH-affected teeth is structurally weaker and more porous due to serum albumin "poisoning"[2], often attributed to prenatal or perinatal trauma[2-4].

Clinical Relevance: MH affects approximately 1 in 5 children worldwide[5]. MH-affected teeth are at a higher risk for post-eruptive breakdown (PEB) (Fig. 1), hypersensitivity and caries[6] than health teeth**. Radiographs inadequately diagnose the depth and extent of hypomineralization; thus, misdiagnosis is common**. Children with MH undergo up to ten times more dental treatment and demonstrate greater dental anxiety than their unaffected counterparts [6-8].

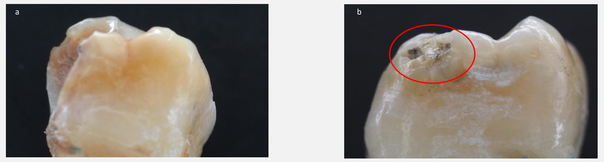

Figure 1: Examples of MH –affected teeth. a) tooth with yellow-brown hypomineralization, b) tooth with PEB circled in red.

Research Question: Are there solutions for accurate detection and characterization of hypomineralization to prevent further tooth damage and improve patient quality of life?

Hypothesis: MH can be accurately characterized with non-invasive spectrophotometry approaches.

Methods

- 25 extracted first permanent molars were collected from the Faculty of Dentistry at the University of Toronto
- Teeth were categorized into three groups using the modified dental defects of enamel (mDDE) index
  - Control (n=7)
  - Hypomineralized (n=8)
  - Other enamel defects (n=10)
- Photographs and radiographs were taken to simulate clinical evaluation.
- Each tooth was then scanned using **optical coherence tomography** (OCT) and **photothermal radiometry** and **luminescence** (PTR/LUM) to create digital scans of selected enamel defects.
- The results of the scans were evaluated and compared

OCT Results

Swept-source light is used to produce non-invasive high-resolution cross-sectional images, known as B-scans (Fig. 2a). B-scans allow for general visualization of the surface and 2mm of subsurface structure. A-scans (Fig. 2b), signal intensity profiles developed from the B-scan, correspond to the enamel characteristics. Depth and volume of MIH lesions were also measured from B-scans.

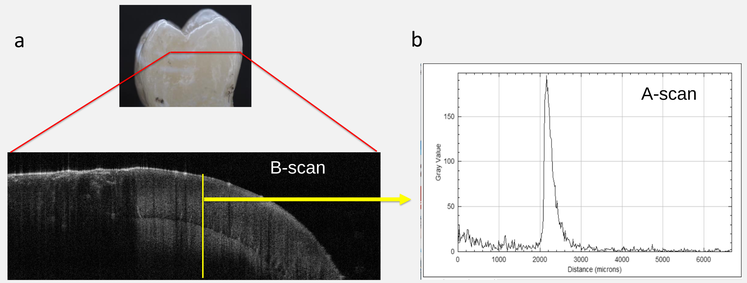

Figure 2: a) B-scan demonstrating the subsurface composition of control enamel (E), dentin (D), and dentin-enamel junction (DEJ), b) A-scan developed from a 10micron section of the B-scan.

Five distinct A-scan patterns were identified for enamel surface type (control, white spot lesions, type 1 MIH, type 2 MIH and MIH with subsurface lesions) (Fig. 3)

Kappa analysis was completed to determine the reliability of the patterns to depict the lesion type:

- **Intra-rater reliability: κ= 0.69**
- **Inter-rater reliability**: **κ=0.66**
- Substantial agreement among raters in correct identification of enamel lesion pattern type

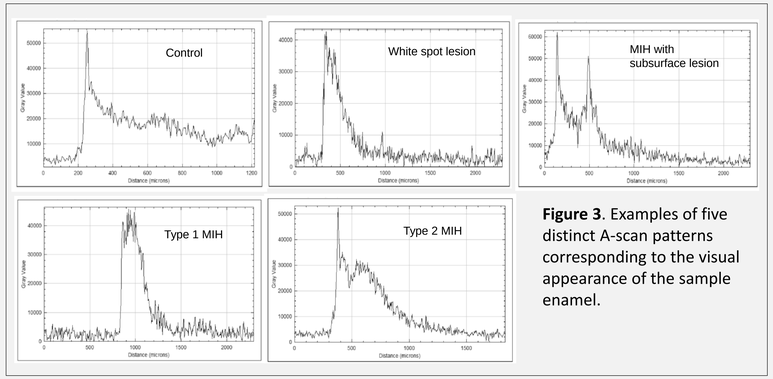

Figure 3. Examples of five distinct A-scan patterns corresponding to the visual appearance of the sample enamel.

PTR/LUM Results

PTR/LUM combines optical and thermal information about tooth structure and captures this in a thermal map

- Red areas: high absorption (ex: protein, caries)
- Blue: areas of low absorption (ex: normal enamel)

Sensitivity: 80% (95%CI: 49-94%)

- PTR/LUM is good at identifying true MIH lesions (Fig. 4)

Specificity: 20% (95%CI: 7-45%)

- PTR/LUM produces a high number of false positives, meaning many non-MIH lesions are incorrectly classified as MIH (Fig. 5)

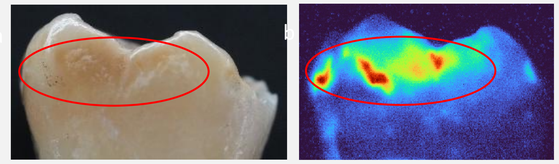

Figure 4. a) A clinical photograph of a tooth sample with visible MIH, circled in red; b) The corresponding thermal scan demonstrates equivalent outlining of the original lesion, circled in red.

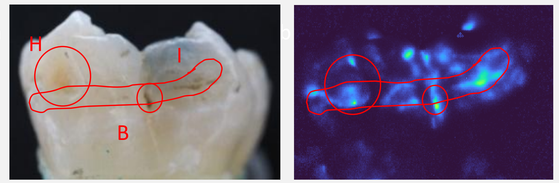

Figure 5. a) A clinical photograph of a tooth sample with no visible MIH, but a hypoplastic lesion (H), buccal caries (B) and insipient caries (I), circled in red; b) The corresponding thermal scan demonstrates equivalent outlining of the original lesions, circled in red.

Conclusion

Through OCT and PTR/LUM, MIH can quantitatively be characterized for improved diagnosis of hypomineralized enamel lesions.

1. OCT :
   - Substantial agreement among raters in correct identification of enamel lesion pattern type
   - Supports validity in pattern recognition and diagnosis of lesion type
2. PTR/LUM:
   - Quantitative severity indicator with high sensitivity but low specificity

References

1. Weerheijm KL. Molar incisor hypomineralisation (MIH). Eur J Paediatr Dent. 2003;4(3):114-20.
2. Hubbard MJ, Mangum JE, Perez VA, Williams R. A Breakthrough in Understanding the Pathogenesis of Molar Hypomineralisation: The Mineralisation-Poisoning Model. Front Physiol. 2021;12:802833.
3. Silva MJ, Scurrah KJ, Craig JM, Manton DJ, Kilpatrick N. Etiology of molar incisor hypomineralization - A systematic review. Community Dent Oral Epidemiol. 2016;44(4):342-53.1.
4. 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 Paediatr Dent. 2022;23(1):3-21.
5. 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.
6. Jälevik B, Klingberg GA. Dental treatment, dental fear and behaviour management problems in children with severe enamel hypomineralization of their permanent first molars. International Journal of Paediatric Dentistry. 2002;12(1):24-32.
7. William V, Messer LB, Burrow MF. Molar incisor hypomineralization: review and recommendations for clinical management. Pediatr Dent. 2006;28(3):224-32.
8. Elhennawy K, Schwendicke F. Managing molar-incisor hypomineralization: A systematic review. J Dent. 2016;55:16-24.