

The use of transillumination in mapping demarcated enamel opacities in anterior teeth: a cross-sectional study.

Running Title: Transillumination in mapping enamel opacities

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Article type : Original Article

The use of transillumination in mapping demarcated enamel opacities in anterior teeth.

Abstract

Background:

Despite intensive efforts for categorizing demarcated enamel opacities, often related to molar incisor hypomineralisation (MIH), there is a lack of descriptive criteria aiming to describe them physically outside the scope of color and size. This is most likely due to the indices focusing on molar, not anterior teeth.

Aim:

The aims of this study were to map and classify demarcated lesions on permanent anterior teeth using reflected and transilluminated light. The association between classification and related lesion characteristics was also examined.

Design:

Permanent anterior teeth with demarcated opacities related to MIH were selected. For each tooth, standardized photographs were taken using transmitted and reflected light. Each lesion was mapped and classified according to its color, lesion size, surface integrity and type. The data were analyzed using the Chi-square and Fisher exact tests. Logistical regression analysis was performed to identify the risk of PEB.

Results:

There were significant relationships between lesion size, color and type with surface integrity. Lesion type and size were more important than lesion color for assessing the risk of PEB. There was also a significant relationship between lesion size and lesion color.

Conclusions:

Lesion size and type are significant clinical parameters for assessing the risk of PEB on enamel opacities related to MIH.

Keywords: Transillumination, MIH, Enamel hypomineralisation, image analysis, Intra-oral devices, In vivo imaging

Introduction.

Molar Incisor Hypomineralisation (MIH) is a qualitative developmental defect of enamel affecting a minimum of one first permanent molar, often with involvement of the permanent incisors.¹ Despite MIH having been detected amongst ancient populations^{2,3}, it was first identified in 1987 by Koch and defined in 2001.^{1,4}

MIH lesions differ considerably from sound enamel. Microscopically, these lesions present disorganized enamel prisms and large inter-prismatic spaces occupied by a protein-rich matrix- associated with decreased mineral density, hardness and fracture resistance. This explains the increased surface porosity and post-eruptive breakdown (PEB) of the enamel surface (especially in severe lesions) and the greater susceptibility to dental caries; and also why affected teeth are often hypersensitive.⁵⁻¹⁰

Despite numerous studies to determine the etiological/causative factors of MIH, apart from a general consensus that it is associated with childhood illness and genetic susceptibility, the causative factor(s) are yet to be determined.¹¹

Clinically, in terms of location and boundaries, lesions are located in the middle and incisal/occlusal third of teeth and show a sharp demarcation between affected and sound enamel; lesions vary greatly in terms of size and shape, with a wide variation in color.¹² Anterior lesions can affect the appearance and perception of the affected teeth and 'smile', and may affect quality of life, and improvement of appearance can improve both self and others' perception.¹³

After the definition of MIH, several classifications and indices were proposed to score and record MIH lesions. Among these systems, the European Academy of Paediatric Dentistry (EAPD) criteria are the most extensively used.¹⁴ The EAPD criteria include absence or presence of demarcated opacities, PEB, atypical restorations and extractions due to MIH. The EAPD index only classifies the size of opacities and does not describe or categorize them from a more detailed morphological point of view. Several clas-

sifications and scoring systems have been developed to describe enamel opacities related to MIH morphologically.^{15,16}

Despite intensive efforts for categorizing enamel opacities related to MIH, there is a lack of descriptive criteria aiming to describe them physically outside the scope of color and size. Indeed, most studies include only defects larger than 1 or 2 mm and categorize only the most severe lesion when more than one lesion exists on a surface. This is most likely due to the indices focusing on molar, not anterior teeth.¹⁶

In addition, observation of MIH lesions in reflected light conditions is currently used. However, this method has limitations as it provides only ‘surface information’ of a three-dimensional lesion. Indeed, in reflected light, the incident light enters the lesion, scatters and changes direction and the photons leave the lesion through the enamel surface through which they entered.¹⁷

Recently, it has been suggested that transillumination allows better detection and more lesion body information in comparison with reflected light.^{18,19} Although the use of transillumination for assessing the lesion body of MIH lesions has considerable anecdotal support, it is, however, not thoroughly reported in the literature. As the available classifications and scoring systems are based on observation in reflected light condition, in the present manuscript we propose to describe and map MIH lesions on permanent anterior teeth using reflected and transilluminated light. The association between classification and size of the lesion with PEB and related lesion characteristics will also be examined. The null hypothesis for this study is that there is no association between lesion size, classification, and surface integrity.

Materials and methods

Ethical approval for this observational study was given by the local institutional board of Farhat Hached Hospital, Sousse, Tunisia. (12/2019, IRB:8931) This study was performed at the Dental medicine department of Sahloul University Hospital, Sousse, Tunisia from March 2018 to February 2020. All patients and their guardians (if minors) gave informed consent before the beginning of the study.

Participants

Clinical examination of teeth dried with gauze was performed under standardized lighting using a plane mouth mirror, and individuals with permanent incisors and canines with opacities located on the incisal and middle thirds of the buccal surface were invited to participate in the study, after a diagnosis of MIH according to the definition of Weerheijm¹.

Exclusion criteria

Teeth with resin composite restorations, or previously treated by micro-abrasion, remineralization (fluoride varnish or calcium-based products such as CPP-ACP) or external bleaching were excluded.

Standardized transilluminated and reflected light photography

Clinical images were taken using a digital single lens reflex camera (D7200; Nikon Corp., Tokyo, Japan), and 90 mm macro lens (SP AF90 mm F/2.8 Di; Tamron Co. Ltd, Saitama, Japan) at 1:1 magnification. Using incident light reflected from the buccal surface and transmitted light from the palatal surface, standardized reflected light (RL) and transilluminated photographic images (TL) were taken for each tooth.

For RL images, settings were F/22 aperture at 1/200 s shutter speed and ISO 100, using flash illumination (R1C1 Macro flash; Nikon Corp., Japan) with auto white balance. For TL images, the same parameters were used except ISO was 800 and flash illumination was replaced by a handheld LED transilluminator (Oslux S2.1; Osram Licht AG, Munich, Germany) providing illumination of 125 lux.

Descriptive evaluation of enamel opacity

Images taken in RL and TL were transferred to Keynote 8.2 software (Apple Corp.; CA, USA) and the examiner (OM) isolated the region of interest containing the enamel opacity and the surrounding sound tissue using the selection tool.

For each enamel opacity, descriptive parameters were recorded as follows:

Color: White/Creamy (**non-colored, NC**); Yellow/Brown (**colored, C**). The evaluation of the color was assessed based on the RL images. In presence of both **NC** and **C**, the lesion was recorded as **C**.

Evaluation of surface integrity: Sound surface (**S**), Enamel craze lines (**C**), Post-eruptive breakdown (**PEB**). These parameters were based on the TL and RL images. Parameters of the surface integrity are illustrated in **Figure 1**.

Opacity of the lesion body: Homogenous (**Ho**) or heterogenous (**He**) based on the appearance of the lesion body in TL images. In the presence of **PEB** the opacity was recorded based on the remaining intact tissue observed.

Size: I: less than 1/3 of the tooth surface involved; **II:** at least 1/3 but less than 2/3 of the tooth surface involved; **III:** at least 2/3 of the tooth surface involved.¹⁵ The size was estimated based on the TL images.

Mapping demarcated enamel opacities, lesion Type and ‘peri-lesion ring’:

The mapping of enamel opacities was based on the appearance of the opacity of the lesion body and the number of lesions found in the affected tooth, observed on TL and RL images. Then, lesions were classified into three lesion types as follows (**Figure 2**):

Type 1: Isolated and demarcated opacity with homogeneous opacity/whiteness of the lesion body.

Type 2: Isolated and demarcated opacity with heterogeneous opacity/whiteness of the lesion body. The lesion presents a principal lesion that is strongly opaque/white and extension(s) which are less opaque/white than the principal lesion.

Type 3: Multiple isolated demarcated opacities separated by sound enamel – lesions appear as secondary defects that have decreased size and opacity/whiteness and are positioned adjacent to the Type 1 or 2 primary lesion.

Peri-lesion ring: Thin zone of opacity circling part or all of the principal or Type 1 lesion (**Figure 3**).

When it is present, this accessory defect is not taken into consideration when categorizing the lesion type.

Statistical analysis

Statistical analysis was performed using SPSS Statistics 20 software (IBM SPSS; NY, USA). The data were analyzed using the Chi-square and Fisher exact tests with a level of statistical significance of $p < 0.05$. Logistical regression analysis was performed to identify the risk of PEB.

Results

Distribution

Based on the selection criteria, fifty-five healthy patients (**19** males and **36** females) aged from 7 to 33 years old, with between 1 and 5 affected teeth were included. This enrolment number was estimated adequate for the statistical power needed for this pilot study. In total, 121 teeth, including 91 maxillary teeth, of which 63.6% were maxillary central incisors (**Table 1**). Regarding the lesion Type, 58.7% were Type 1 lesion, 15.7% were Type 2 and 25.6% were Type 3. Besides, regardless of the lesion classification, 31 lesions (25.6%) had a ‘peri-lesion ring’ (**Table 2**).

Quantitative results and results analysis.

There were statistically significant relationships between lesion size, color, type and surface integrity (**Table 2**). Brown/yellow enamel opacities, size III and Type 1 lesions were at higher risk of developing PEB ($p < 0.05$). Logistical regression analysis showed that the lesion type (Pseudo $R^2 = 0.29$) and size (Pseudo $R^2 = 0.17$) were more important than lesion color (Pseudo $R^2 = 0.14$) for assessing the risk of PEB.

There was also a statistically significant relationship between lesion size and lesion color ($p < 0.02$) whereas no relationship was found between lesion type and the color ($p = 0.14$).

Discussion

In the present study, demarcated enamel lesions on anterior teeth related to MIH were mapped according to the appearance of the opacity of the lesion body and the number of lesions found in the affected tooth observed in TL and RL images. The parameters of size, color, and surface integrity were also categorized. The results of this study showed that there is a statistically significant relationships between lesion size, type and surface integrity. The null hypothesis was thus rejected.

Whilst visual mapping is feasible using both TL and RL, it is important to highlight that transilluminated images may represent a promising imaging method for mapping demarcated hypomineralised enamel lesions on anterior teeth. Indeed, transillumination increases the contrast between sound and hypomineralised enamel, allowing better assessment of lesion number and better discrimination of hypomineralised lesions on anterior teeth.¹⁸ Besides, as TL images can more accurately detect extension and location of enamel opacities in anterior teeth in comparison with RL images, the use of RL images alone may also lead to under-diagnosis.¹⁸ TL images can also be used to differentiate between homogenous and heterogeneous opacity within the lesion body.¹⁹ The ability of transillumination to highlight differences in opacity is not surprising, as teeth are illuminated from their lingual surfaces and the light passes through the tooth structure until it reaches the buccal surface. Interaction between light and the hypomineralised lesion leads to a strong scattering effect resulting in a decrease of light transmission. Thus, depending on the degree of hypomineralisation, the opacity varies depending on the quantity of light that reaches the buccal surface.^{6,10,17,20}

From this perspective, while Type 1 lesions present a homogeneous opacity, Type 2 and 3 lesions differ from Type 1 lesions due to the presence of heterogeneous opacities located in lesion extensions and secondary defects.

The variability of visual appearance of hypomineralised lesions is not surprising. Mechanical, mineral density and chemical properties are highly variable not only within lesions but also in the transition region from affected to unaffected enamel.²⁰⁻²³ Therefore, with respect to lesion ‘extensions’ and secondary lesions, their less opaque appearance in TL images would lead us to reasonably assume that they are less affected in terms of the degree of hypomineralisation than the principal defect.

In the present study, PEB is only present in Type 1 lesions. It is reported that yellow/brown lesions are more likely to have PEB, so the present results are all the more surprising as no relationship was found between color and lesion type; but previous data relates to molar not anterior teeth.¹² Enamel mechanical characteristics may explain the link between the type of enamel opacity and the risk of PEB, as the decrease in mechanical properties (in terms of hardness and modulus of elasticity) is directly related to the degree of hypomineralization.¹² Thus, we can hypothesize that heterogeneous lesions (Type 2 and 3) have lesser reduction in the mechanical properties than homogenous lesions which putatively explains why no PEB was observed in Type 2 and 3 lesions.

A thin ‘peri-lesion ring’ of opacity circling the principal lesion after the transition region linking affected and unaffected enamel was observed in several instances. As the transition region is less affected in terms of degree of hypomineralisation than the lesion body, the reasons for the presence of the ‘peri-lesion ring’ remain unclear.^{21,22} We hypothesize that as the positioning of the ‘peri-lesion ring’ is always gingival to the primary lesion, it may be attributed to a continuation of the pathological process of MIH after a period of quiescence – however, further research is required.

The larger the lesion, the higher the chance it was yellow/brown in color, with size also increasing prevalence of PEB or craze lines (**Table 2**). To the authors’ knowledge, this is the first study to correlate anterior demarcated hypomineralised lesion size with risk for PEB and craze lines or color. The susceptibility of larger lesions to PEB and craze lines may be related to the fact that larger lesions have more chance of being affected by masticatory forces which promote these mechanical defects.²⁴ Besides, we can hypothesize that the larger lesions are a result of a greater and/or longer insult during amelogenesis, which could lead to a greater degree of hypomineralisation and weaker mechanical characteristics and therefore greater risk for developing PEB, craze lines or to be colored.^{8,10}

Regarding lesion color, in the present study yellow/brown lesions have a higher prevalence of PEB compared to white/creamy lesions, in accordance with recent literature.^{9,24} It should, however, be noted that this association was not strongly significant in comparison with the lesion type or size. This finding is interesting as no information is available for assessing the risk of PEB on anterior teeth. Besides, while le-

sion color is currently used for assessing the risk of PEB for molars, ^{12,25,26} other studies did not confirm this association^{20,27} suggesting that other factors should be considered in assessing the severity of the MIH lesion and its likelihood in breaking down.^{12,20}

The strengths of the present study include the use of TL and RL images to map enamel hypomineralised lesions on anterior teeth which may be of value from an epidemiological perspective. Based on the results of this study, the lesion size and type are significant clinical parameters for assessing the risk of PEB of enamel opacities related to MIH on anterior teeth. Although the classification of enamel opacities according to the type of lesion needs to be validated and studied further with a larger sample, these preliminary results can help in treatment planning and in the prediction of possible subsequent outcomes of the affected teeth. The study is slightly limited by its cross-sectional nature which assesses the defects at a single moment in time and by its in vivo nature with histologic assumptions. Therefore, future ex vivo histologic studies should be sought to corroborate the findings of this study, however, this may be unlikely due to the paucity of extracted permanent anterior teeth.

Why this paper is important to paediatric dentists:

- Transilluminated images may represent a promising imaging method for mapping hypomineralised enamel lesions related to MIH on anterior teeth.
- Categorization of MIH-related lesions on anterior teeth may be of value from an epidemiological point of view and may help treatment planning and prediction of possible future outcomes of affected teeth.
- The lesion size and type are significant clinical parameters for assessing the risk of PEB on MIH-related enamel lesions on anterior teeth.

Conflict of interest

The authors declare no conflict of interest.

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Table 1: Distribution of the lesions according to tooth type.

	Central incisor (%)	Lateral incisor (%)	Canine (%)	Total (%)
Maxillary (%)	77 (63.6)	8 (6.6)	6 (5)	91 (75.2)
Mandibular (%)	17 (14)	9 (7.4)	4 (3.4)	30 (24.7)
Total (%)	94 (77.7)	17 (14)	10 (8.3)	121

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Table 2: Distribution of clinical parameters.

Variable	Baseline n	Craze lines n (%)	PEB n (%)	P	Yellow/Brown lesion n (%)	P
Color of lesion						
White/Creamy	62	13 (21)	4 (6.5)	<u>0.03*</u>	Not applicable	
Yellow/Brown	59	10 (17)	14 (24)			
Size of lesion						
I	45	4 (9)	3 (6.5)		15 (33)	
II	34	7 (20.6)	2 (5.9)	<u>0.0001</u> *	18 (52)	<u>0.02*</u>
III	42	12 (28.5)	13 (31)		26 (62)	
Type of lesion						
1	71	10(14)	18 (25)		40 (56)	
2	19	5 (26.3)	0	<u>0.001*</u> *	7 (37)	<u>0.14*</u>
3	31	8 (26)	0		12 (39)	

*: Chi-square test, $\alpha = 5\%$.

** : Fisher exact test, $\alpha = 5\%$.

Table 2: Distribution of clinical parameters.

Variable	Baseline n	Craze lines n (%)	PEB n (%)	P	Yellow/Brown lesion n (%)	P
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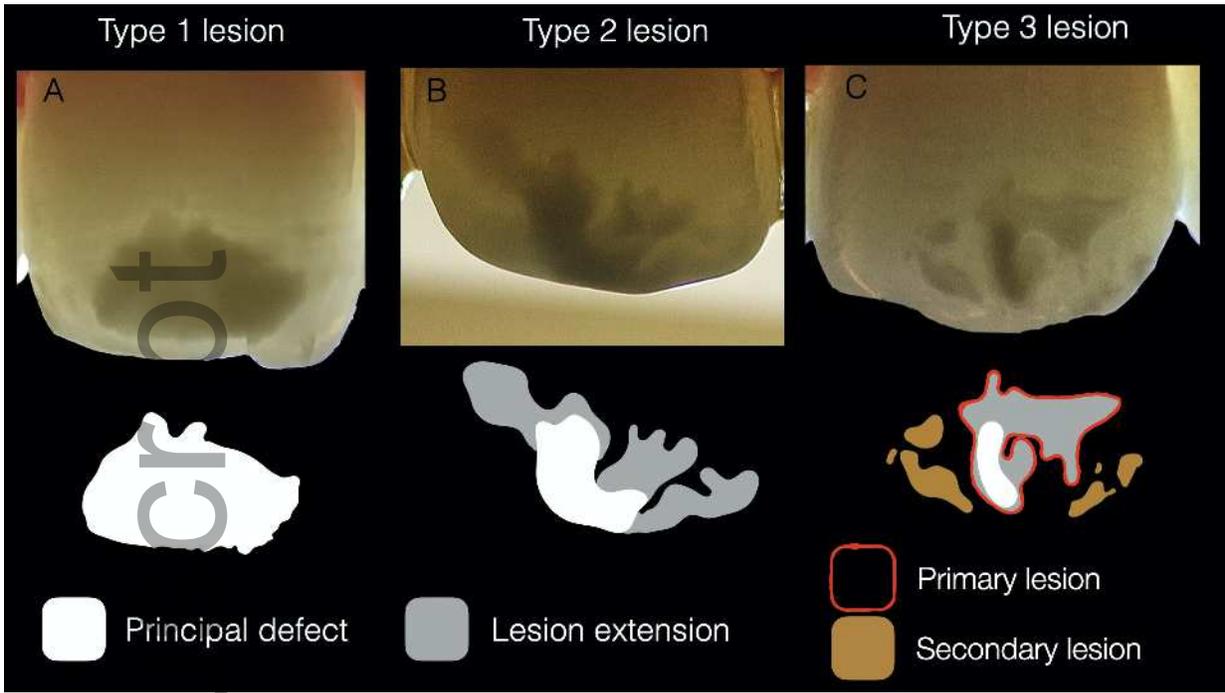
Statistically significant.

Figure1: Transilluminated and reflected images representing the craze lines (C) in blue arrows and the post-eruptive breakdown (PEB) assessed white arrows.

Figure 2: The mapping of enamel opacities based on the appearance of the opacity of the lesion body and the lesion number on the affected tooth lead to differentiate three lesion types. While Type 1 (A) lesion presents an isolated and demarcated opacity with homogeneous opacity of the lesion body, Type 2 (B) presents a non-homogeneous opacity of the lesion body with extension(s) which are less opaque than the principal defect. Type 3 (C) lesion is defined as multiple isolated demarcated opacities separated by a sound enamel - appear as secondary defects revolving around a type 1 or 2 defect. Note that secondary defects show decreased size and opacity in comparison with the primary lesion (type 2).

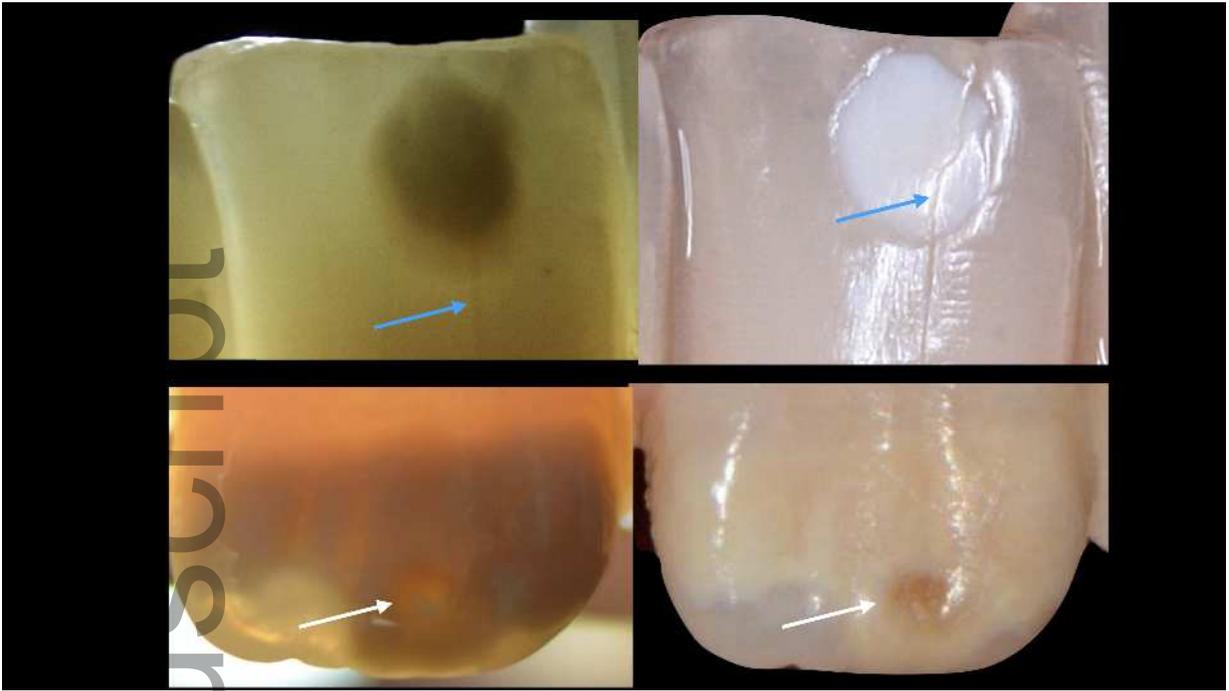
Figure 3: Transilluminated images (A, D) and reflected images (B,C) representing the thin ‘peri-lesion ring’ of opacity circling the MIH lesion (White arrow). Note that the ‘peri-lesion ring’ is observed after the transition region linking affected and unaffected enamel.

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