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Original research

Prevalence and predictors of molar-incisor hypomineralization among Egyptian children: a cross-sectional study

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Purpose
The primary aim of this study was twofold: first, to assess the prevalence of molar incisor hypomineralization (MIH) within a cohort of Egyptian children and, second, to investigate the potential correlation between MIH and various factors, including age, sex, birth complications, and endogamous marriage.

Materials and Methods
This cross-sectional investigation took place in Egypt's Delta region, with approximately 3000 children aged between eight and twelve years being recruited for participation. The European Academy of Pediatric Dentistry (EAPD; 2003) criteria served as the diagnostic tool for identifying MIH cases. Upon detection of clinical signs or symptoms indicative of MIH, parents were queried regarding any potential birth complications or endogamous marriages. Lesion severity levels were diagnosed using Mathu-Muju and Wright criteria.

Results
The prevalence rate for MIH was found to be 7.2%. Molars exhibited higher susceptibility rates than incisors (64.8% vs 35.2%), with approximately 37% of participants displaying severe scores, followed by mild (33.8%) and moderate (29.2%). Male subjects had significantly more occurrences than females, with positive correlations identified between MIH incidence rates alongside each gender category as well as both birth complications and endogamous marriages.

Conclusion
Children born from complicated pregnancies or whose parents are related should receive frequent check-ups from pediatric dentists during their first permanent molar eruption period. so that early detection of MIH can be facilitated allowing timely intervention.

Keywords: *Incisors, molars, hypomineralization, children, Egyptians*

Introduction

Molar incisor hypomineralization (*MIH*) is characterized as a "qualitative defect of enamel, with systemic origin, that presents as demarcated anomalies in one to four first permanent molars (*FPMs*), which are frequently accompanied by affected incisors (1). The translucency of the tissue is compromised due to hypomineralization, resulting in color changes in the enamel; areas that are white or yellowish/brownish can be observed without any alteration in thickness (2). This condition causes tooth sensitivity, posteruptive dental tissue breakdown and predisposition to dental caries. Additionally, it creates opacity on anterior teeth, leading to cosmetic and psychosocial issues. Furthermore, *MIH* affects both the quantity and quality of tooth tissues, making the selection of appropriate restorative materials and techniques more challenging (3,4).

The ideal moment to diagnose *MIH* is when it is present clinically, regardless

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of whether it affects primary or permanent teeth, 8 or 9 years of life is the best time for diagnosing this condition (2). The examination should be carried out on clean and moist teeth. The clinical signs of *MIH* vary depending on its severity and can manifest as white-creamy opacities, yellow–brown opacities, posteruptive enamel breakdown, or atypical caries located on at least one *FPM* with or without incisor involvement. To qualify as *MIH*, the lesions must measure more than 1 mm in size (5,6). For diagnosing *MIH*, the widely used criteria are those established by the European Academy of Pediatric Dentistry (7).

The frequency of *MIH* varies widely, ranging from 2.8% to 44%, depending on the population and country under investigation. Nonetheless, recent meta-analyses suggest that approximately 13%-14% of children globally are affected by *MIH* (8,9). In Egypt, multiple research studies have been conducted to determine the prevalence of *MIH* among children aged between eight and twelve years old using different measurement criteria across various regions. The results generated by these studies were inconsistent, as Saber *et al*. (10) demonstrated a prevalence rate of 2.3% at Cairo and Future Universities; similarly, Abd El Ghaffar *et al*. (11) exhibited 2.7% at Cairo University, whereas Senosy *et al*. (12) showed an occurrence rate of 4.9% at Fayoum Governorate. However, Osman *et al*. (13) determined a significantly higher percentage of approximately 14.2% in Giza Governorate alone.

The etiology of *MIH* remains obscure, with two theories postulated: environmental insults during the prenatal, perinatal, and postnatal periods or a genetic origin (14,15). The genetic basis for *MIH* was highlighted by Vieira and Kup, who believed that variations in genes involved in enamel formation can be confirmed, thus necessitating consideration of genetic etiology (15). Perinatal complications such as labor difficulties, cesarean section delivery, premature birth and low birth weight have also been associated with *MIH* (1). Although some studies suggest correlations between several potential factors and *MIH*, most provide insufficient evidence to identify causal factors (14).

Managing *MIH* can be a complex process for both dental professionals and patients alike. Children suffering from this condition often require more extensive dental treatments, with repeated visits being necessary due to the high incidence of failed restorations because of weakened tooth structure (16). Furthermore, children with severe *MIH* defects tend to experience a lower quality of life regarding oral health compared to their unaffected peers - an issue that may be compounded by the presence of caries (17,18). As such, it is crucial that we gain an understanding of the prevalence and underlying causes of *MIH* to prevent its negative impact on affected individuals. Despite this pressing need, no research has been conducted on the prevalence of *MIH* in Egypt's Delta region. Therefore, our study aims not only to determine how widespread this condition is in this area but also to explore any potential associations between birth complications or endogamy and *MIH* development.

Materials and Methods

Study design and settings

This cross-sectional investigation was carried out at the Pediatric Dentistry Outpatient Dental Clinics situated in two prestigious university hospitals, Mansoura, and Delta Universities, during the period between September 2022 and October 2023. These two clinics offer dental services to a diverse range of patients hailing from several governorates in the Delta Region, including Dakahlia, Damietta, and Kafr El-Sheikh. A convenient sample size of three thousand children was selected from these outpatient clinics for our study.

Subjects and ethical considerations

The ethical committee at Mansoura and Delta University's dental colleges approved the protocol of this study (#FODM-RC-2023-00100/12 February,2022). Prior to the commencement of the study, the purpose and methodology were discussed and clarified with the parents of the children, and their consent was obtained. It was assured that their participation would not affect the provision of their recommended services, and they had the option to decline participation in the study at any time. Furthermore, they were informed that their data would be kept confidential.

Inclusion criteria

This study recruited physically fit and socially adept children of both sexes, aged 8 to 12 years, who possessed at least one fully or partially erupted first permanent molar and/or incisor.

Exclusion criteria

The study did not encompass children exhibiting generalized developmental defects such as amelogenesis and dentinogenesis imperfecta, dental erosion, fluorosis, hypoplasia, diffuse opacities, tetracycline stains, white spot lesions or Turner's hypoplasia. Additionally, children who wore fixed orthodontic appliances were also excluded from the study.

Data collection

Investigators' training and calibration

The examination was conducted by a pediatric dentist and a dental public health demonstrator. The two examiners underwent theoretical training, which involved identifying 25 photographs of patients with *MIH* and 40 photographs depicting other enamel defects. They were then calibrated through the identification of 30 photographs each of *MIH* and other enamel defects. Intraexaminer and interexaminer reliability were assessed using Cohen's kappa coefficient, which yielded values of 0.95 and 0.90, respectively, for *MIH* examination.

Clinical examination

The participating children underwent a clinical examination using artificial light, and infection control guidelines were strictly adhered to. To obtain an accurate diagnosis, the teeth were meticulously cleaned utilizing gauze pieces and explorer tools. *MIH* was determined if the child displayed a clinical picture of at least one first permanent molar (*FPM*) with the involvement of one or more permanent incisors

(5). Lesions that exceeded 1 mm in size were classified as *MIH* (6). The *EAPD* (2003) criteria (19) were employed for scoring *MIH*, which included demarcated opacity (scored 1), posteruptive enamel breakdown (scored 2), atypical restorations (scored 3), extracted molar due to *MIH* (scored 4), and unerupted molar due to *MIH* (scored 5). Whenever there were observable clinical signs present, parents were asked about any birth complications and endogamous marriages. Finally, lesion severity levels ranging from mild to severe cases were diagnosed based on the Mathu-Muju and Wright criteria (20). Mild MIH manifests as demarcated opacities situated in nonstress bearing regions, unaccompanied by caries in the affected enamel and devoid of hypersensitivity. In cases where incisor involvement is present, it typically presents as a mild form. Moderate MIH is characterized by delineated opacities on molars and incisors, posteruptive enamel breakdown that affects only one or two surfaces without involving the cusps, and a need for atypical restorations. Additionally, patients with this condition may experience normal dental sensitivity. Severe MIH is characterized by posteruptive enamel breakdown, crown destruction, caries associated with affected enamel, and a history of dental sensitivity and aesthetic concerns.

Statistical analysis

The data were gathered, structured, and scrutinized by means of *SPSS* version 20.0 (*IBM* Corp, Armonk, NY, USA). Standard descriptive statistics such as frequencies were computed to ascertain the features of the sample. The chi-square test was employed to compare two or more frequencies. Linear regression analysis was performed to identify the influence of significant predictors on dependent variables. The confidence interval was established at 95%, and a p value less than 0.05 was deemed statistically significant.

Results

The average age of the study participants was 9.55±1.31 years, with males comprising 48% and females comprising 52%. The prevalence of *MIH* in the studied population was found to be 7.2%, equivalent to a total of 216 cases out of a sample size of 3000 children (Figure 1). Among these affected children, severe *MIH* occurred in approximately in 37% (80) of cases, while mild and moderate scores were reported in approximately 33.8% (73) and 29.2% (63), respectively (Figure 2). About the *EAPD* score distribution, Figure (3) indicates that teeth with demarcated opacity accounted for 53.9% (297), whereas those with enamel breakdown or atypical restorations made up 38.3% (211) and 7.8% (43), respectively. There were no extracted or unrecorded molars due to *MIH*. Of the 216 affected children, a total of 30.1% (65) had experienced birth complications. Moreover, endogamous parents represented 26.4% (57) of the affected children (Figure 4).

Most of the impacted teeth were molars, accounting for 64.8% of cases. In terms of incisors, a moderate rating on the *MIH* scale was predominant at 12.3%, with severe and mild scores following at 9.4% and 7.3%, respectively. Interestingly, among affected molars, severe *MIH* had the highest prevalence rate at 29.4%, while mild and moderate scores accounted for 28.9% and 15.8%, respectively (as per Table 1).

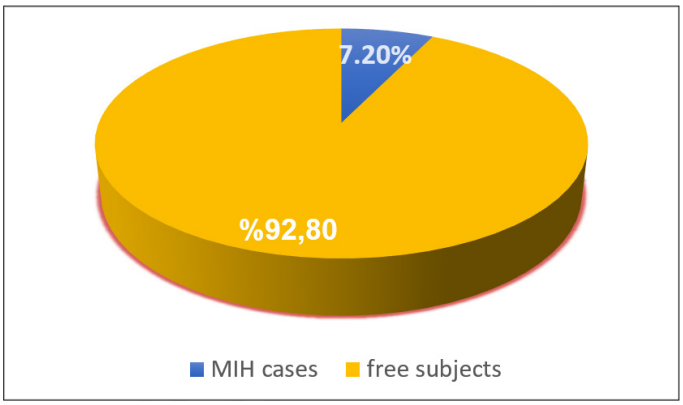

Figure 1. *Distribution of MIH among studied children.*

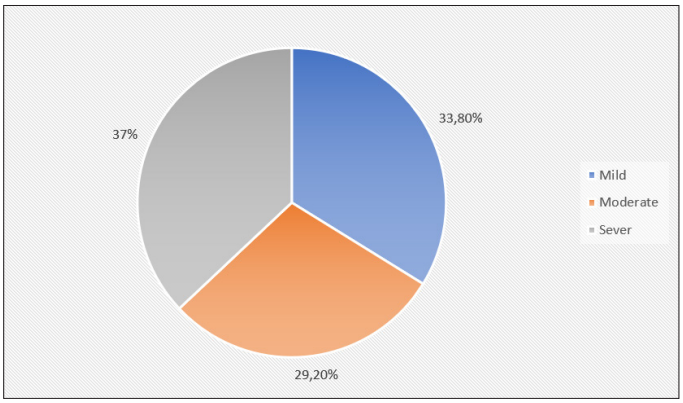

Figure 2. *Mild, moderate, and sever MIH scores among studied children.*

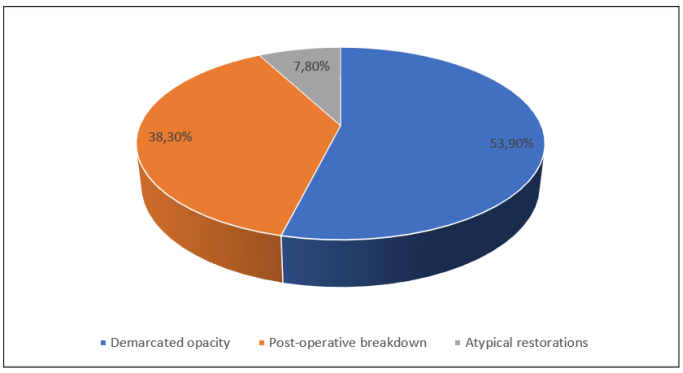

Figure 3. *Distribution of EAPD scores among affected teeth.*

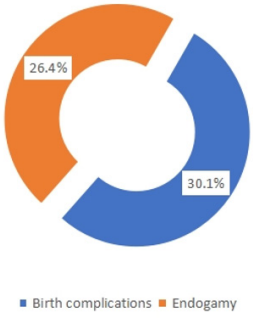

Figure 4. *Distribution of birth complications and endogamy among affected children.*

As evidenced in Table 2, the male cohort exhibited a higher *MIH* score than their female counterparts (145 vs. 71). Notably, females with mild *MIH* scores exceeded those with severe scores (34 vs. 17), while for males, the opposite held true: children with severe *MIH* scores were more prevalent than those with mild ones (63 vs. 39). A statistically significant difference was detected between genders (p<0.0001). Table 3 illustrates the correlation between *MIH* scores and age. Among the children examined, 122 cases were identified in those under ten years of age, whereas 94 cases were found in those over the age of ten. In younger children, mild *MIH* was predominant, with a total of 45 cases compared to severe *MIH*, which had only 36 cases reported. Conversely, for older children, there was an increased incidence of severe MIH, with a total of 44 reports as opposed to mild *MIH*, which had only been reported in 28 instances. The linear regression model incorporating all four predictors yielded an adjusted R^2 of 0.319, with F (352.76) = 64.194 and P <0.0001. The results indicate a significant positive correlation between *MIH* and each gender, birth complications, and endogamous marriage, with the most substantial impact observed for birth complications (Beta=0.366, P <0.001), followed by endogamous marriage (Beta =0.231, P=0.001), and gender (Beta=0.084, P <0.001). Please refer to Table 4 for further details of these findings.

Table 1. *Distribution of MIH score across affected molars and incisors (N=551)*

Affected teeth	Mild	Moderate	Severe	Total
	N (%)	N (%)	N (%)	N (%)
Incisors	40 (7.3)	68 (12.3)	52 (9.4)	194 (35.2)
Molars	159 (28.9)	87 (15.8)	162 (29.4)	357 (64.8)
Total	199 (36.1)	155 (28.1)	214 (38.8)	551 (100)
Chi-square	12.6	0.333	10.53	8.49
P value	0.0004*	0.564	0.001*	0.004*

**: Statistically significant difference by Chi-square test at p<0.05.*

Table 2. *Association between gender and MIH scores.*

Gender	MIH status	Mild	Moderate	Sever	Total
	N (%)	N (%)	N (%)	N (%)	N (%)
Females	Present	34 (2.2)	20 (1.3)	17 (1.1)	71 (4.6)
1559	Absent	1525 (97.8)	1539 (98.7)	1542 (98.9)	1488 (95.4)
Males	Present	39 (2.7)	43 (3)	63 (4.4)	145 (10.1)
1441	Absent	1402 (97.3)	1398 (97)	1378 (95.6)	1296 (89.9)
Test of significance	Chi-square	0.871	10.541	31.068	34.005
	P value	0.351	0.001*	0.0001*	0.0001*

**: Statistically significant difference by Chi-square test at p<0.05.*

Discussion

Enamel hypomineralization arises from an imbalance in the activity of ameloblasts responsible for forming enamel during its maturation phase (21). It affects one or more permanent molars and may include incisors (22). Given that a lack of knowledge regarding prevalence rates and risk predictors may lead to rapid caries progression, dental tissue loss, and sensitivity issues associated with MIH, we conducted a study exploring these factors among Egyptian children.

The present study's findings unveiled a *MIH* prevalence of 7.2% among participants. In Egypt, Saber *et al*. (10) and Abd El Ghafar *et al*. (11) reported a lower prevalence than our study at 2.3% and 2.7%, respectively. Conversely, Osman *et al*. (13) demonstrated a higher MIH prevalence of 14.2%. Moreover, in certain Arabic countries such as Saudi Arabia, the *MIH* prevalence was recorded at 15.2% in Riyadh (23)

Table 3. *Association between age and different MIH scores.*

Age	MIH status	Mild	Moderate	Sever	Total
	N (%)	N (%)	N (%)	N (%)	N (%)
8 to less than 10 (n=1799)	Present	45 (2.5)	41 (2.3)	36 (2)	122 (6.8)
	Absent	1754 (97.5)	1758 (97.7)	1763 (98)	1677 (93.2)
10 to 12 (n=1201)	Present	28 (2.3)	22 (1.8)	44 (3.7)	94 (7.8)
	Absent	1173 (97.7)	1179 (98.2)	1157 (96.3)	1107 (92.2)
Test of significance	Chi-square	0.088	0.701	7.669	1.178
	P value	0.77	0.40	0.006*	0.278

**: Statistically significant difference by Chi-square test at p<0.05.*

Table 4. *Association between age, gender, birth complication, endogamy, and MIH.*

Predictors	Unstandardized Coefficients	Standardized Coefficients	T	P value	95.0% Confidence Interval for B	
	B	Beta			Lower Bound	Upper Bound
Age	0.002	0.004	0.283	0.777	-0.013	0.018
Gender	0.043	0.084	5.493	0.0001*	0.028	0.059
Birth complications	0.650	0.366	16.868	0.0001*	0.575	0.726
Endogamy	0.438	0.231	10.664	0.0001*	0.358	0.519

**: Statistically significant difference at p<0.05. Dependent variable: Total MIH*

and 8.6% in Jeddah (24). In Syria (25), the prevalence was noted to be as high as 39.9%, while Jordan recorded rates of 13.17% (26) and 17.6% (27). At Khartoum State in Sudan (28), it was found to be 20.1%. Globally, a Meta-analysis conducted 2021 showed global *MIH* prevalence of 13.5% (29). Moreover, the systematic review conducted at the year-end of 2022 revealed that the rate of *MIH* prevalence stood at 15.05% (30), whereas at Chennai, it was 12.9% in 2018 (19). At Rome in Italy the prevalence was 18.2% in 2022 (31). Israel marked 10.3% (32) during their research conducted in 2023. The variation observed across these studies could be attributed to differences with respect to sample size, whereby some used larger samples compared to others. Additionally, sampling techniques varied, with some being randomized, while others were not. Furthermore, different diagnostic criteria were employed by different researchers for assessing *MIH*, which also played a part in the disparity observed among study outcomes.

The prevalence of severe *MIH* scores (37%) was higher among the children in our study compared to mild or moderate scores. Similarly, Lopes *et al*. (29) demonstrated that 36.3% of the *MIH* cases were moderate to severe. This differs from findings reported by Zawaideh *et al*. (27), where 44% of participants showed a mild score. Conversely, Hamdan *et al*. (26) found that most of their sample had severe scores. They attributed this outcome to the breakdown of enamel with age, as well as an inherent weakness in enamel structure, which increases susceptibility to *MIH*. Our results supported this notion, as almost half of affected children aged ten and above had severe *MIH*, while those younger than ten years old exhibited only mild symptoms.

The current investigation revealed a higher incidence of affected teeth displaying demarcated opacity compared to those exhibiting posteruptive enamel breakdown. This finding was congruent with Allazzam *et al*. (24), who demonstrated a 56.5% occurrence of demarcated opacity versus a 26.1% prevalence of postoperative breakdown. Furthermore, Saber *et al*. (10) reported that out of 148 teeth analyzed, only 11 exhibited enamel breakdowns, while the rest displayed demarcated opacity. Additionally, Almuallem *et al*. (23) found that in *FPMs* and permanent incisors, there was a respective occurrence rate of 68.6% and 96.5% for demarcated opacity cases.

With regard to the affected incisors and molars, this study indicates that a greater number of teeth were impacted in molars compared to incisors. Moderate *MIH* scores were observed in most affected incisors (12.3%), while severe scores were more widely distributed among the affected molars (29.4%). These findings differ from those reported by Abd El Ghafar *et al*. (11), who found that only 30% of the affected teeth were molars. Conversely, Padavala and Sukumaran (19) demonstrated that 13 children had affected molars versus 9 with affected incisors. Moreover, Abdalla *et al*. (28) reported that 65.8% versus 34.2% of the impacted teeth were molars and incisors, respectively. Lopes *et al*. (29) revealed that affected incisors were seen in 36.6% of the study participants. Almuallem *et al*. (23) and Al-Nerabieah *et al*. (25) supported our results by highlighting *FPMs* as being more severely impacted than permanent incisors, an observation also made by Weerheijm *et al*. (22). They noted that hypomineralization severity is generally less pronounced in impacted incisors when compared to their molar counterparts. Additionally, Nisii *et al*. (31) 71.4% of the affected teeth were molars.

In terms of gender, males exhibited a higher *MIH* score than females. However, this result was not corroborated by Saber *et al*. (10), Osman *et al*. (13), and Almuallem *et al*. (23), who found no significant differences between sexes. Furthermore, Abdalla *et al*. (28) discovered that the prevalence of *MIH* was higher among females than males at 53% versus 47%, which aligned with the findings of Allazzam *et al*. (24) and Padavala and Sukumaran's study in 2018 (19). These studies demonstrated that there was a higher incidence rate of *MIH* among males than females.

Regarding the association between gender and *MIH* prevalence, it should be noted that there is a significant relationship between them. Nevertheless, this finding did not concur with Allazzam *et al*. (24), Mishra and Pandey's research in 2016 (32), or Alhowaish *et al*'s study in 2021 (33); they failed to show any meaningful correlation between sex or age groups' prevalence rates of *MIH*. Bahrololoomi *et al*'s research conducted in 2020 (34), however, showed a substantial correlation between the extent, severity and size of lesions caused by *MIH* based on gender criteria. Moreover, Nisii et *al*'s examination performed in 2022 (31) indicated that patient gender stood out as an essential variable within the optimal model since it significantly influenced both probability levels associated with suffering from *MIH* symptoms.

Our study demonstrated a significant association between birth complications and *MIH*, which is consistent with the findings of Bukhari *et al*. (30) and Pitiphat *et al* (35). Furthermore, Juárez-López *et al*. (36) and Berenstein *et al*. (37) did not find an association between *MIH* and prematurity, cesarean birth, or other birth complications. Our findings may be attributed to the fact that complications during birth can cause suffering in the child and deficiencies in oxygenation that affect amelogenesis (24). Additionally, a meta-analysis of 45 studies indicated that perinatal factors such as cesarean section, prematurity, and birth complications can lead to hypoxia, which is a greater risk factor for *MIH* (38).

The current study observed an endogamous marriage to be correlated with *MIH*. This finding is consistent with Jeremias *et al*. (39), who reported evidence of the genetic influence on *MIH*. This result supports the multifactorial nature of *MIH* etiology, which was explained by genetic variation in the *AMELX* gene, which is associated with amelogenesis imperfecta and *MIH*. The *AMELX* gene plays a crucial role in amelogenesis, as it codes for amelogenin, the primary protein of dental enamel produced by ameloblasts during the secretion stage of amelogenesis (40).

The patient sample utilized in this study may not accurately represent the overall population, as they were primarily sourced from pediatric outpatient dental clinics. The distinction between *MIH* and other developmental defects, or early caries, can be challenging, which may result in an underestimation or overestimation of the prevalence of *MIH*.

Conclusion

Based on the findings of this study, a moderate prevalence of *MIH* (7.2%) was reported in the study population of children in comparison to other study results. Molars were found to be more commonly affected by *MIH* than incisors.

The severe score was more prevalent than other scores. Demarcated opacities were widely distributed among affected teeth. Males were found to be more affected by *MIH* than females. Significant correlations were observed between *MIH* and sex, birth complications, and endogamy. It is imperative that children who have experienced birth complications or have relatives as parents or those who are currently undergoing the process of erupting their first permanent molars receive regular monitoring by a pediatric dentist to detect any instances of molar incisor hypomineralization at the earliest possible stage.

Türkçe öz: *Mısır'lı çocuklarda büyük azı-kesici diş hipomineralizasyonunun prevalansı ve belirleyicileri: kesitsel bir çalışma Amaç: Bu çalışmanın birincil amacı iki yönlüydü: birincisi, bir grup Mısırlı çocuk arasında büyük azı-kesici diş hipomineralizasyonu (MIH) prevalansını değerlendirmek ve ikincisi, MIH ile yaş, cinsiyet, doğum komplikasyonları ve akraba evliliği gibi çeşitli faktörler arasındaki olası korelasyonu araştırmak. Hastalar ve Yöntemler: Bu kesitsel araştırma, Mısır'ın Delta bölgesinde gerçekleştirildi ve sekiz ile on iki yaşları arasında yaklaşık 3000 çocuk katılım için seçildi. MIH vakalarını belirlemek için Avrupa Pediatrik Diş Hekimliği Akademisi (EAPD; 2003) kriterleri tanı aracı olarak kullanıldı. MIH'ı gösteren klinik belirti veya semptomlar tespit edildiğinde, ebeveynlere olası doğum komplikasyonları veya akraba evlilikleri hakkında sorular soruldu. Lezyon şiddet seviyeleri Mathu-Muju ve Wright kriterlerine göre teşhis edildi. Sonuçlar: MIH prevalans oranı %7,2 olarak bulundu. Büyük azı dişlerinde kesici dişlere göre daha yüksek duyarlılık oranları görüldü (%64,8'e karşı %35,2), katılımcıların yaklaşık %37'si ciddi skorlar gösterirken, bunu hafif (%33,8) ve orta (%29,2) dereceler izledi. Erkek denekler, kadınlara göre anlamlı derecede daha fazla vaka gösterdi ve MIH insidans oranları ile her iki cinsiyet kategorisinin yanı sıra hem doğum komplikasyonları hem de akraba evlilikleri arasında pozitif korelasyonlar tespit edildi. Sonuç: Komplike gebeliklerden doğan veya ebeveynleri akraba olan çocuklar, ilk daimi büyük azı dişlerinin sürme döneminde pediatrik diş hekimleri tarafından sık sık kontrol edilmelidir. Bu şekilde MIH'ın erken tespiti sağlanarak zamanında müdahale yapılabilir. Anahtar kelimeler: kesici dişler, büyük azı dişleri, hipomineralizasyon, çocuklar, Mısırlılar*

Ethics Committee Approval: The ethical committee at Mansoura and Delta University's dental colleges approved the protocol of this study (#FODMRC-2023-00100/12 February,2022).

Informed Consent: The informed contents were provided by the parents or legal guardians of the participants.

Peer-review: Externally peer-reviewed.

Author contributions: AME, RMA participated in designing the study AME, RMA participated in generating the data for the study. AME, RMA participated in gathering the data for the study. AME participated in the analysis of the data. AME wrote the majority of the original draft of the paper. AME, RMA participated in writing the paper. AME, RMA has had access to all of the raw data of the study. AME, RMA, DA has reviewed the pertinent raw data on which the results and conclusions of this study are based. AME, RMA, DA have approved the final version of this paper. AME, RMA, DA guarantees that all individuals who meet the Journal's authorship criteria are included as authors of this paper.

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