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Research Article

Prevalence and Clinical Characteristics of Molar-Incisor-Hypomineralization in School Children in Riyadh, Saudi Arabia

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ABSTRACT:

Objective: To evaluate molar-incisor-hypomineralization (MIH) prevalence, clinical characteristics, and severity amongst school children in Riyadh, Saudi Arabia.

Subjects and Methods: Randomly selected, healthy third- and fourth-grade students (aged 8–10 years) attending elementary schools in Riyadh, and children of the same age attending dental clinics at the College of Dentistry, King Saud University, were examined for the presence of MIH, its clinical characteristics, and severity.

Results: The sample studied consisted of 924 children, 447 (48.4%) of whom were boys. There were 376 children, (199 females and 177 males), with at least 2 index teeth affected (prevalence = 40.7%). A total of 133 (35.4%) had only molar hypomineralization (MH), whereas 243 (64.6%) had molars and incisors involved (MIH). The mean number of affected teeth per child was 6.6 ±3.6 (3.3 for molars and 3.2 for incisors). The chi-Square test showed no association between the distribution of hypomineralization and age (P = 0.115). Children with severe hypomineralization predominated across all age groups, with the 10-year-old group having more severely affected children (71.9%) compared to 8- and 9-year-old groups (P = 0.000). Proportional t-test showed no statistically significant difference (P>0.05) between males and females in the occurrence of MH or MIH, and in the severity of the hypomineralization. Upper molars were more affected than lower molars, whilst upper incisors were more affected than lower incisors.

Conclusion: Enamel hypomineralization is a common feature in the dentition of 8–10-year-old children in Riyadh, Saudi Arabia. There is no association with age and no gender predilection.

Key words: molar-incisor-hypomineralization, children, prevalence, clinical characteristics, and severity.

INTRODUCTION

Newly erupted Permanent First Molars (PFMs) with opacities or disintegrating enamel are being observed with increasing frequency amongst school children seeking dental treatment in Riyadh. These defects were first documented in Sweden in the late 1970s[1]. The condition has, at times, been referred to as 'idiopathic enamel hypomineralization'[1], 'cheese molars'[2], 'hypomineralized permanent first molars'[3] and 'nonfluoride hypomineralization'[4]. The term 'molar-incisor-hypomineralization' (MIH) was proposed by Weerheijm and co-workers (2001a)[5], who defined the condition as a developmental disorder of teeth involving the 'hypomineralization of systemic origin of one to four PFMs and also frequently associated with affected permanent incisors'. Weerheijm *et al*. (2001a)[5] and Lygidakis *et al*. (2003)[6], however, reported that the risk of involvement of permanent maxillary incisors appears to increase when more PFMs are affected. From a clinical perspective, the defects present as a continuum from creamy-white demarcated opacities to yellowish-brown opacities at the time of tooth eruption[7]. Studies have shown a distinct margin between the affected and sound enamel, with the former characterised by a normal thickness of enamel, but nonetheless soft with less mineral content and altered translucency due to subsurface porosities[3,8,9].

The severity and extension of this defect can vary, not only amongst patients but also within one patient. The variation might demonstrate randomly distributed opacities in individual molars or more than one molar in the same individual, whilst another molar of the same patient might exhibit severe defect and the secondary breakdown of enamel or atypical restoration[5,10,11]. The possible etiology and the exact mechanism of the development of MIH is not fully elucidated. A recent literature review, however, suggest several environmental factors acting systemically as linked to the development include: pre- and perinatal conditions, childhood illnesses that are common in the first three years of life, such as respiratory disorders, asthma, otitis media, tonsillitis, chickenpox, pneumonia, measles or high fever[6,9,12-18]. Importantly, the prolonged use of antibiotics during infancy

has also been implicated[13,16,19], with the condition attributed to disrupted ameloblastic function during the transitional and maturational stages of amelogenesis[13]. Importantly, the systematic etiological factors acting for longer periods during enamel mineralisation and maturation tend to produce more affected teeth with more severe defects[14].

The MIH is worldwide, and has received much attention in the international literature. It appears to have no distinct ethnic or racial predilection. Most prevalence studies on MIH have been carried out in Europe, South America and Australia. In a review of MIH prevalence studies, Jalevik (2010)[8] observed that wide variation in defect prevalence reported was as a result of the use of different indices and criteria, examination variability, methods of recording, and different age groups. A comparison of the results from different studies was therefore difficult. The review of recent studies in MIH show prevalence rates as ranging from between 2.4% through to 44%[8,17,20]. Importantly, there is little information available in regards the occurrence of MIH amongst school children in the Arabian Peninsula. In Saudi Arabia specifically, only one study was conducted, which reported a prevalence of 8.6% of MIH in Jeddah[16]. The aim of the current study was to add to the body of knowledge and establish baseline data on MIH prevalence, clinical characteristics, and severity in school children in Riyadh, Saudi Arabia.

Subjects and methods

Study population

The subjects studied consist of healthy third- and fourth-grade students (aged 8–10 years) attending elementary schools in Riyadh city, as well as children of the same age attending dental clinics at the College of Dentistry, King Saud University. The children were from mixed socioeconomic background. Approval of the study was obtained from the ethics committee of the College of Dentistry Research Center and thereafter from the President General for education office in Riyadh, who facilitated the visit to the selected school. The schools were randomly selected from a list of all elementary schools for boys and girls, obtained from Ministry of Education to represent five different educational zones (Central, Northern, Southern, Eastern and Western) of Riyadh city.

The purpose and nature of the study information were sent through to the parents of the selected children, seeking their consent for the children to participate in the study. For those children attending dental clinics, the study was explained directly to the accompanying parents, with consent obtained. The following were the inclusion criteria: children aged 8–10 years; life-long residents in Riyadh; and four PFM and at least six incisors erupted. The exclusion criteria were those children whose parents did not consent to their participation, those with tetracycline staining, dental fluorosis, and amelogenesis imperfecta or generalised enamel hypoplasia. Children undergoing orthodontic treatment at the time of examination were also excluded. Opacities occurring in permanent incisors but not in at least one FPM were not included.

Clinical Examination

Two trained paediatric dentists (NH and MD) who took part in a pilot study preceding this study examined the children. Both examiners were calibrated using a group of 20 MIH patients who were not a part of the study. In order to assess the reproducibility of the diagnostic criteria application, patients were re-examined after two weeks. The intra- and inter-examiner reliability of the assessment was determined using Cohen's kappa statistic. (intra-examiner reliability: NH = 0.91, MD = 0.89, and inter-examiner reliability of 0.87).

The children were examined whilst seated on a chair facing the light source. PFMs and incisors were cleaned using cotton roll. The children were asked to close their mouth briefly and then to reopen. The index teeth (PFM and incisors) were then examined wet using the judgment criteria for the diagnosis of MIH, as established 2003 by the European Academy for Paediatric Dentistry, EAPD[11], and subsequently revised[21]. The teeth must have more than one-third crown erupted height in order to be recorded. The presence of enamel opacity, extraction due to MIH, post-eruptive enamel breakdown (EBD) and atypical restoration (AR) were evaluated. According to Elfrink *et al*. (2015)[20], prevalence studies of MIH should include at least 300 children, chosen at random.

Statistics

The recorded data were entered into a computer utilising the FOX PRO program. Statistical Package for Social Sciences (SPSS) Version 20 for windows (SPSS Inc., Chicago, IL) software was used to analyse the data. Descriptive statistics, including frequency, means, standard deviations, percentage and tables, were used to describe the data. Chi-square and Proportional t-test were used to test the association and difference between the tested variables, with a level of significance set to 0.05.

Results

The sample studied consisted of 924 children, 447 (48.4%) of whom were boys. Their mean age was 9.1 years (SD 0.8, range 8.0–10.0), with a male-to-female ratio of 0.9:1. Most of the children (92.5%) had their 12 index teeth fully erupted. There were 376 children (199 females and 177 males), with at least two index teeth affected, giving a prevalence of 40.7%. In the 376 children affected, 2476 teeth were involved (1259 PFMs and 1217 permanent incisors). The mean number of the affected teeth per child was 6.6 ±3.6 (3.3 for molars and 3.2 for incisors). The distribution of affected teeth amongst the children can be seen detailed in Table 1.

Of the 376 affected children, 133 (35.4%) had only molar hypomineralization (MH), whereas 243 (64.6%) had molars and incisors involved (MIH). Hypo-mineralization was recorded as mild (demarcated opacities only) in 122 children (32.4%) whilst was severe (presence of enamel break down or atypical restoration) in 254 (67.6%). All incisors were mildly affected. The study subjects were divided into three groups according to their age (8, 9 and 10 years). The chi-Square test showed no association between the distribution of hypomineralization and age (P = 0.115). Children with severe hypomineralization predominated all age groups, whilst the 10-year-old group had more severely affected children (71.9%) than those in the 8- and 9-year-old groups (P = 0.000). MIH-affected children were more than MH-affected children in all age groups. Nine-year-old children were affected by MIH more so than the other age groups (P = 0.000). The proportional t-test showed no statistically significant difference (P>0.05) between males and females in the occurrence of MH or MIH, and in terms of the severity of hypomineralization (Table 2).

A large proportion of children with hypomineralized molars (59.8%) had all their PFMs molars affected (Table 3),

whereas more than one-third of the children with MIH (35.4%) had all of their incisors involved (Table 4), whilst 14.9% had all of the index teeth involved (Table 1). A proportional t-test showed that upper molars were more keenly

affected than lower molars, and upper incisors more so than lower incisors. Upper centrals are more affected than lower centrals, whilst upper laterals were more than lowers (Table 5).

Four lower molars were extracted due to hypomineralization.

Of the 1259 hypomineralized molars in the affected children, 755 (60.0%) had EBD; 204 (27.0%) were restored (AR). A proportional t-test showed that lower molars were significantly more affected by EBD (P = 0.02) and had more AR (P = 0.001) than uppers (Table 6).

Table 1: Distribution of hypomineralized teeth among affected children

No. of affected teeth per child	Frequency %	Total
2	36 (9.6%)	72
3	30 (8%)	90
4	90 (23.9%)	360
5	15 (4%)	75
6	42 (11.2%)	252
7	18 (4.8%)	126
8	34 (9%)	272
9	10 (2.7%)	90
10	28 (7.4%)	280
11	17 (4.5%)	187
12	56 (14.9%)	672
Total	376 (100%)	2476

Table 2: Age and hypomineralization severity

Age(years)	All children	Affected	Mild		Severe		MH		MIH	
8	291 (31.5%)	113 (38.8%)	35 (30.9%)		78 (69.1%)		41 (36.3%)		72 (63.7%)	
9	330 (35.7%)	149 (45.1%)	55 (36.9%)		94 (63.1%)		48 (32.2%)		101 (67.8%)	
10	303 (32.8%)	114 (37.6%)	32 (28.1%)		82 (71.9%)		44 (38.6%)		70 (61.4%)	
Chi_Sq P-value	P=0.115		P=0.000*				P=0.000*			
Total	924 (100%) M F	376 (40.7%) M F	122 (32.4%) M F		254 (67.6%) M F		133 (35.4%) M F		243 (64.6%) M F	
	447 477 P-Value = 0.512	177 199	56 (45.9%)	66 (54.1%)	121 (47.6%)	133 (52.4%)	60 (45.1%)	73 (54.9%	117 (48.1%)	126 (51.9%)
			P=0.365		P=0.451		P=0.260		P=0.564	

*=statistically significant

Table 3: Distribution of hypomineralized molars within age groups

Age Years)	Affected molars (16,26,36,46)			Total
	2 molars	3 molars	4 molars	
8	26	16	71	113
9	32	22	95	149
10	36	19	59	114
Total children	94 (25%)	57 (15.2%)	225 (59.8%)	376 (100%)
Total teeth	188	171	900	1259

Table 4: Distribution of hypomineralized incisors within age groups

Age (years)	Affected children	1 incisor	2 incisors	3 incisors	4 incisors	5 incisors	6 incisors	7 incisors	8 incisors	Total incisors
8	113	5	14	3	18	5	4	4	19	343
9	149	8	25	3	17	2	2	5	39	504
10	114	7	10	0	16	2	4	3	28	370
	376 (100%)	20 8.2%	49 20.2%	6 2.5%	51 21.0%	9 3.7%	10 4.1%	12 4.9%	86 35.4%	1217
		243(64.6%) Total children with affected incisors								

Table 5: Number of affected teeth in each arch.

Teeth	Affected	Total	Proportional t-test
16	330	667 (88.7%) upper molars	P=0.000*
26	337		
16	330	592 (78.7%) lower molars	
26	337		
11	212	425 (56.5%) upper centrals	P=0.000*
21	213		
31	123	241 (32.1%) lower centrals	
41	118		
12	163	327 (43.5%) upper laterals	P=0.000*
22	164		
32	114	224 (29.8%) lower laterals	
42	110		

*=statistically significant

Table 6: Enamel breakdown and atypical restoration of hypomineralized molars

Molars	EBD		AR	
	Yes	No	Yes	No
16	168 (44.7%)	208 (55.3%)	40 (10.6%)	336 (89.4%)
26	187 (49.7%)	189 (50.3%)	39 (10.4%)	337 (89.6%)
36	197 (52.4%)	179 (47.6%)	64 (17.0%)	312 (83.0%)
46	203 (54.0%)	173 (46.0%)	61 (16.2%)	315 (83.8%)
Total	755	749	204	1300
!Uvs L	P=0.02*		P=0.001*	

!= Difference between upper and lower affected molars *=statistically significant

Discussion

This research has highlighted that enamel hypo-mineralization is prevalent when analysing the dentition of children aged 8–10 years in the city of Riyadh, Saudi Arabia. Despite the fact that the research sample might not be generalizable to the population of children in the country as a whole, nonetheless, baseline data pertaining to the distribution of enamel hypo-mineralization and the clinical characteristics of such across urban school children is, irrespectively, provided. This then provides a foundation for a more wide-ranging, largescale work to be carried out on a national scale.

For a number of years, the dental profession has been informed in regards enamel 'hypoplasia', especially in the case of molars and, albeit to a less significant degree, in anterior teeth. One of the most pressing concerns has centred on the way in which such issues can be managed in a clinical domain, without the attention or direct emphasis towards aetiology and epidemiology[22].

MIH age frequency has been determined for each age (8, 9 and 10 years) cohort on an individual basis, as highlighted in the 2003 EAPD[11] meeting. In this particular investigation, it was established that, across this age range, the majority of all 12 index teeth (i.e. 4 PFMs and 8 incisors) demonstrated eruption with the exception of 5% of cases of the children; in these instances, there was no eruption seen across some of the lateral incisors.

This age was outlined and identified as being the most suitable when seeking to complete a comprehensive evaluation and diagnosis in regards MIH, predominantly owing to the fact that, at this point in their lives, the majority of children show eruption in the first permeant molars and central incisors.

Accordingly, there will be the potential to clearly identify the imperfections prior to any colour-restoration covering such defects. Furthermore, there would be only very minimal risk that restorations and/or caries would mask the enamel hypo-mineralization.

In an effort to ensure the sample population under analysis and examination was consistent, evaluation was carried out by two investigators following calibration and reliability checks.

In some European countries, epidemiological studies are known to have been conducted during the late-1980s and through to the present date, although such works have been lacking in other locations in the world.

The issue is believed to be positioned in the fact that all epidemiology studies carried out prior to 2003—when, notably, new MIH criteria were outlined—were not considered precise in providing an accurate defect prevalence[22].

This work is carried out in Saudi Arabia, a major country located in the Middle East, which has demonstrated a prevalence rate of 40.7%. Such a prevalence is far greater than in other published works across the globe, including that in the KSA's Western territory (Jeddah)[16]. Importantly, this mentioned study outlined a prevalence equal to only 8.6%, which is far lower than what has been identified in the current study population.

Such significant differences between the findings of the aforementioned work and this study can be problematic to rationalise; nonetheless, when examining the samples tested and the methodology implemented, it may be stated that the samples showcase differences. In the work done in Jeddah, the

sample was chosen from children aged 8–12 years present at a teaching paediatric dentistry clinic; thus, the sample is recognised as more convenient than random. Moreover, whilst the sample size in the previous work was 267, this work has taken a sample encompassing almost four times this figure. It is noteworthy to mention that Elfrink and colleagues stated that to conduct an MIH prevalence study a minimum random sample size of 300 is required[20].

Upon completing a literature review in regards MIH, a total of three other research carried out in Arab settings were identified, with the countries of context Iraq[23], Jordan[24] and Libya[25]. These studies highlighted prevalence rates of 21.5%, 17.6% and 2.9%, respectively. As can be seen, such lower prevalence rates are apparent when comparing these works with the current study. It is worth highlighting that the aforementioned works adopted the EAPD criteria, as per that applied in this work.

Despite the fact that epidemiological works from various other areas have undergone comparison and this could be misleading owing to the differences in diagnostic criteria, it also remains that various other factors could be influential in this regard, such as sample selection, environmental and etiological considerations, and lesions included.

On an international scale, when considering MIH prevalence, the highest rate recorded is in that of the 2009 work of Soviero *et al*[26] conducted in Brazil. Followed by works completed in Denmark[27], Finland[28] and India[29] (notably with prevalence rates of 37.3%, 25% and 27%, respectively).

Another work provides data pertaining to the prevalence of MIH amongst children in Brazil living in rural area that is recognised as high (24.9%)[9]. In a pilot unpublished work conducted, data from Kuwait demonstrated a prevalence rate comparable to that identified in this work (around 40%).

The findings detailed above, especially those in the Middle Eastern context, provide a solid justification for a standardised epidemiological work centred on providing more relevant comparative data on the prevalence of MIH.

When drawing a comparison between the results garnered in the current study with the only study published on MIH prevalence in East Asia, notably in Hong Kong, a far greater rate is determined in the Saudi population when contrasted with the Chinese[30] (40.7% vs 2.8%). Regardless of the fact that both study populations comprised children, there is nonetheless the need to emphasise that, in East Asia study, the mean age was 12; this is recognised as potentially having impacted the diagnosis when considering that older children would have a greater potential to demonstrate caries, wear and restoration that could mean any developmental defects are masked.

Moreover, despite the recognition that a larger proportion of females were affected by MIH and MH, such a difference was not viewed as statistically significant. In a number of other works[24,31,32], gender predilection was identified, with more girls affected than boys. It is postulated that, when considering dental development, girls are more advanced than boys, meaning the eruption of first permanent molars might be more advanced amongst girls. This would mean hypo-mineralized molars are more keenly exposed to masticatory forces, thus resulting in the more common post-eruptive enamel breakdown amongst females than in males of the same age[24]. Importantly, a number of other studies have found a greater prevalence rate of MIH across boys when compared with girls[9,23,26].

In contrast, however, when examining children in Saudi Arabia, the only available previous study emphasised no notable gender predilection as identifiable between boys and girls, although the MIH was nonetheless identifiable across more boys than girls[16].

Despite the fact that children displaying these problems were categorised as severe across all age groups, it remains that a greater degree of severity was witnessed across those aged 10 years old, whilst those aged 9 years were affected by MIH more so than other ages. Such results are supported by other studies, such as those by Zawaideh *et al*. (2011)[24], Bhaskar & Hegde (2014)[33] and Gurrusquieta *et al*. (2017)[34]. When considering rationalisations behind findings, this result of a greater prevalence of MIH within a particular age group could be associated with particular environmental factor present at that year of birth.

When examining MIH's clinical characteristics in the sample under examination, a wide range of the problem was identified, with MIH-affected children recognised as making up as much as two-thirds of the entire sample (64.6%), whilst those affected with MH equated to just over one-third (35.4%). Such a result is seen to be aligned with the works carried out on Greek and Indian populations[22,35]. On the other hand, the studies carried out by Jasulaityle *et al*. (2007)[36] and Zawaideh *et al*. (2011)[24] detailed greater prevalence of molar hypo-mineralization when contrasted with MIH. When considering the results on a per-child basis, the mean number of affected teeth amongst those diagnosed with hypo-mineralization was recognised as high (6.6). Such a finding is seen to be comparable to the work of Lygidakis *et al*. (2008b)[22].

In spite of the fact that the variations witnessed in regards the susceptibility of upper and lower permanent molars to MIH has been highlighted in the current study, with a greater degree of prevalence identified in the case of upper permanent molars than lower permanent molars, this has not been proven with certainty. Nonetheless, other studies display similar findings[22,23,37].

Other works have highlighted that there is a greater prevalence witnessed across mandibular molars in their sample populations[29,33,36],with a number of elements potentially influencing this finding, including the sitting position of the individual whilst being examined, lighting conditions, and the criteria adopted, to name a few.

The greater prevalence observed in regards maxillary molars' hypo-mineralization could also be owing to the later eruption of such teeth when compared with mandibular molars. Importantly, the earlier eruption of such teeth could mean that caries has already formed when examination takes place, meaning they are not identified as being affected with a developmental defect[31].

In alignment with the literature available in the field of MIH, the amount of maxillary central incisors affected were seen to be greater than in the case of lower incisors[23,26,29,30]. Furthermore, the findings have shown that, overall, lateral incisors are not as intensely affected in regards enamel-related problems, whereas the lower lateral incisors are the least affected. This is seen to be in par with the results garnered in the works of Lygidakis *et al*. (2008b)[22]and Parikh *et al*. (2012)[38]. In contrast, in the study of Zawaideh *et al*. (2011)[24], which took a sample of children from Jordan, the conclusion was drawn that lower lateral incisors were more commonly hypo-mineralized than upper laterals. Nonetheless, the difference identified in this study was not considered statistically significant.

In support of the study carried out by Chawla *et al*. (2008)[31], severe enamel defects were recognised more so than mild

hypo-mineralization across all of the age groups examined. When hypo-mineralized teeth erupt into the oral cavity, these become vulnerable to post-eruptive breakdown and caries as a result of the mastication forces. In the current study, the number of teeth demonstrating such problems totalled 755 vs 749 teeth with no enamel breakdown. If considering the potential for MIH/MH to be owing to systemic factors, there would then be the expectation that all four first permanent molars would demonstrate problems to comparable degrees. Nonetheless, the current work provides support with anecdotal clinical reports providing explanations for varying severity in terms of hypo-mineralization in the index teeth in a particular dentition. When considering each dentition, there notably is variation across the severity and number of teeth seen to be affected, reflecting those teeth mineralized when adverse events occur. There is the possibility that a group of ameloblasts could be active at varying points throughout the amelogenesis process of an individual tooth, which would go some way to rationalising the severity of the defects and the asymmetry of such across affected dentitions. When examining the hypo-mineralization group, more than half (almost 60%) demonstrated problems with their first permanent molars, whereas more than one-third were affected across all of their incisors. It is therefore considered that MH and MIH form an "MIH spectrum" of developmental defects of enamel, where MIH is the more severe form of hypo-mineralization disturbing both molars and incisors, and the MH is the minor form of MIH affecting FPMs but not the incisors.

In line with the precipitating increase across duration and/or severity, more teeth are affected, with the mineralization effect recognised as clearer. In this regard, the suggestion is made by Chawla *et al*.[31] that the clinical diagnosis of MH or MIH should only be performed when all FPMs and permanent incisors have demonstrated eruption; until this time, MIH diagnosis can be made but only on a provisional basis, with a clear diagnosis only possible when all permanent incisors have erupted and can therefore be positioned on the MIH spectrum.

In terms of managing MIH across children, the potential steps forward have been examined in the study of Silva *et al*. (2017)[39]. Hypo-mineralized teeth management may be seen to span from the placement of a fluoride-releasing glass-ionomer cement, with the aim of providing some degree of interim protection, through to the more intense and aggressive restorative process of onlay and crown placement. However, there is also the potential to complete in-home applications of CPP-ACP products in an attempt to achieve remineralization, which could result in the lesser need of extensive treatment and fewer sensitivity complaints.

Significantly, in a recent survey[40] carried out across dental students and dentists located in Riyadh, Saudi Arabia, a lack of insight into the management and overall diagnosis of MIH cases was found, with approximately 60% of the study sample stating they were unaware of a defect named MIH. When considering the notably high prevalence of MIH in the current investigation, there is a recognised need for continuing education courses in this regard—particularly encompassing both the diagnosis and the management of MIH and MH cases.

Conclusion

Based on the results of this investigation, the following conclusions can be made:

•Across children aged 8–10 years, enamel hypo-mineralization is common.

•MIH is seen to be more prevalent than MH across all age subgroups.

•Sever enamel hypo-mineralization was identified more commonly than milder defects.

•When examining the age and gender association with enamel defects, statistical significance was not identified

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