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Canines are affected in 16-year-olds with molar–incisor hypomineralisation (MIH): an epidemiological study based on the Tromsø study: "Fit Futures"

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Abstract
Aim This was to determine the prevalence, distribution of affected teeth and severity of MIH in adolescents from Northern Norway.
Methods It was part of a cross-sectional health survey Fit Futures including 16-year-olds from two neighbouring municipalities, Tromsø and Balsfjord.
Results The prevalence of MIH was 13.9 % (110 of 794). The maxillary first permanent molars (FPMs) were 1.6 times more frequently affected than in the mandible ($P < 0.001$). The FPMs on the right side were 1.2 times more often affected than the FPMs on the left side ($P = 0.038$). The maxillary incisors were 2.5 times more often affected than the incisors in the mandible ($P < 0.001$). The proportions of participants whose canines and incisors were involved were 22.8 and 41.8 %, respectively. Altogether 201 FPMs were affected; 54.0 % of these had opacities only, 24.3 % had posteruptive breakdown (PEB), 18.8 % had atypical restorations, and 3.0 % had been extracted due to MIH. The buccal surfaces were most often affected in FPMs. More severe lesions were found in the mandibular FPMs compared with the maxillary FPMs ($P = 0.002$). In the lower canines, only opacities were recorded, while in the upper jaw 13.0 % of the affected canines showed PEBs. The distribution of MIH in the dentition was not symmetrical.
Conclusion The prevalence of MIH (13.9 %) in the study population of 16-year-olds from Northern Norway is consistent with previous Scandinavian reports. The distribution pattern shows that one participant in four with MIH had at least one affected canine. Further studies are needed to describe the localisation of defects on the enamel surface and to relate these findings to enamel thickness and the duration of amelogenesis.

Keywords Molar–incisor hypomineralisation · Prevalence · Epidemiology · Norway

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Introduction

The prevalence of molar–incisor hypomineralisation (MIH) varies considerably between different regions ranging from 2.4 % in Germany and Bulgaria (Dietrich et al. 2003; Kukleva et al. 2008) to 40.2 % in Brazil (Soviero et al. 2009). In Nordic countries, the prevalence ranges from 17.0 % in Finland (Alaluusua et al. 1996a) to 37.3 % in Denmark (Wogelius et al. 2008), but so far no study has been conducted in Norway.

The most frequently affected teeth in MIH are first permanent molars (FPMs) and permanent incisors, which are mineralised around the time of birth. The second primary molars and the tips of the permanent canines can also be involved occasionally (Weerheijm et al. 2001, 2003).

MIH was so named by Weerheijm et al. (2001), and judgment criteria for diagnosis were defined in 2003 (Weerheijm et al. 2003) and modified in 2010 (Lygidakis et al. 2010), but the condition had already been described many years ago by Koch et al. (1987). According to the recommendations of the European Academy of Paediatric Dentistry (EAPD) (Lygidakis et al. 2010), the best age for a cross-sectional study of MIH would be eight years. To evaluate the clinical variability of the enamel disturbances over time (Lygidakis et al. 2010), a longitudinal study design with examinations from the age of 6 up to 12 years is recommended. Kühnisch et al. (2014) recommended including 14- to 16-year-olds, allowing more complete monitoring of MIH (Jälevik 2010; Lygidakis et al. 2010; Kühnisch et al. 2014).

To our knowledge, only two publications (Dietrich et al. 2003; Bhaskar and Hegde 2014) have mentioned that permanent canines were affected in some individuals, but no data about the distribution of affected permanent canines are available. The median age of full eruption of maxillary permanent canines (both sexes) was 12.5 years and for mandibular permanent canines, 11.5 years (AlQahtani et al. 2010).

One feature of MIH typically observed is its non-symmetricity. It seems that this has not hitherto been thoroughly reported in the literature.

The affected enamel in MIH teeth has a tendency to accumulate more severe defects over time due to posteruptive breakdown (PEB) of hypomineralised enamel (Weerheijm et al. 2001).

The present study aimed (1) to report on the prevalence of MIH in Norwegian adolescents, (2) to examine the distribution of the affected teeth and (3) to describe the severity of the enamel disturbances 5–10 years after eruption.

Materials and methods

In 2010–2011, all first-year upper secondary school students in the two neighbouring municipalities in Northern Norway, Tromsø and Balsfjord, were invited to join the cross-sectional health survey *Fit Futures* with an attendance rate of 92.9 % (Winther et al. 2014). All participants gave written informed consent. Participants aged 16 years and above signed at the study site, while younger participants brought written permission from their guardian. In the present study, only individuals born in 1994 (380 girls and 414 boys) were included (Fig. 1). The Norwegian Data Protection Authority and The Regional Committee of Medical and Health Research Ethics (reference number 2009/1282 and 2011/1702/REK nord) approved the study in July 2010 and October 2011, respectively.

As a part of the clinical examination, eight photographs (Canon EOS 60D; Canon 105 mm; Sigma EM-140 DG) were taken in the following order: the buccal surfaces of the teeth in the first and fourth quadrant (#1), the corresponding surfaces in the second and third quadrant, the buccal surfaces of the maxillary and mandibular anterior teeth (#3), the occlusal surfaces of the upper teeth (#4 & 5)

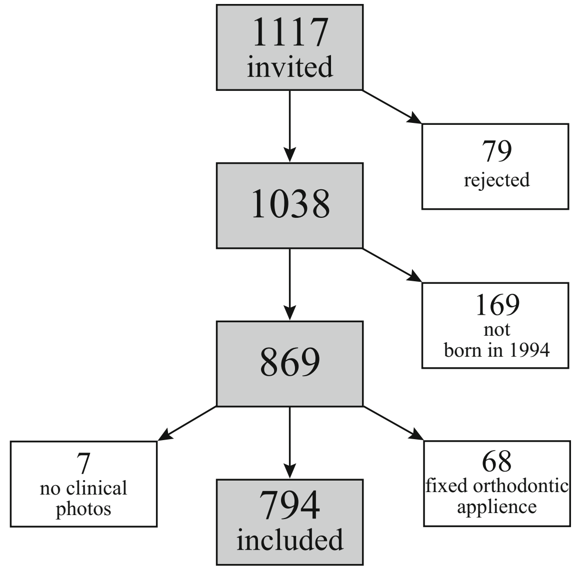

Fig. 1 Participant inclusion flow chart

and lower teeth (#6 & 7) and the palatinal surfaces of the upper anterior teeth (#8).

The clinical photographs of the 794 adolescents were shown on a flat screen in a room with indirect, standardised lighting and examined independently by three experienced dentists (examiners AS, ABT, KS). In line with the EAPD guidelines of MIH (Lygidakis et al. 2010), the buccal, occlusal and palatinal/lingual surfaces of all FPMs were examined as well as the labial surfaces of all central and lateral incisors and canines. Characteristics such as opacities (white cream/yellow-brown colour), PEB, atypical restorations and extractions judged as being due to MIH were recorded. Opacities >1 mm were registered (Lygidakis et al. 2010). The examiners recorded individually and independently. A joint score was decided for each recording, and a consensus was reached through discussion when individual scores differed. Classification of MIH-affected teeth and surfaces was based on the most severe diagnosis recorded (opacity < PEB < atypical restoration).

Affected MIH teeth were given a dichotomous score classifying the lesions as *mild* or *severe*. Surfaces or teeth with opacities only were defined as *mild* (grade 1). Surfaces or teeth with PEB, atypical fillings and teeth that had been extracted were defined as *severe* (grade 2). If an opacity and PEB or restoration occurred on the same surface, it was scored as *severe* (Lygidakis et al. 2010).

To calculate the intra- and inter-examiner agreement, a re-examination was performed one month later. The examiners repeated the registrations of 10 % ($n = 11$) of cases randomly selected with MIH diagnoses and 10 % ($n = 68$) without MIH diagnoses. The cases were mixed and "blinded" before the re-examination. The codes which were used in the kappa calculations (tooth level) were: 0 = MIH free and 1 = MIH affected.

Statistical analysis

The data were analysed using the SPSS package version 21.0 (IBM SPSS Inc., Chicago, IL, USA). Inter-observer analyses (kappa statistics) were performed with MedCalc version 13 (MedCalc Software, Ostend, Belgium).

Results

The mean (SD) age of the participants was 16.6 (±0.33) years (range 15.8–17.3 years). The inter-observer variation is reported in Table 1. The three examiners (O1–O3) had the following intra-observer variation expressed as kappa (95 % CI) 0.88 (0.80–0.95), 0.89 (0.81–0.96) and 0.86 (0.78–0.94).

The prevalence of MIH was 13.9 % (110 of 794 participants). Girls were more often affected than the boys (16.3 vs. 11.6 %; $P = 0.054$). The mean numbers of affected index teeth, FPMs and incisors were 2.9, 2.0 and 0.9, respectively, in participants with MIH. In about half of the participants with MIH (50.9 %), the number of affected teeth was limited to one or two teeth. About a quarter (27.3 %) had three or four affected teeth, while 21.8 % had five or more affected teeth (Fig. 2).

Only one FPM was affected in 48.2 % of individuals with MIH, while 30.0 % had two, 12.7 % had three, and 9.1 % had four affected FPMs. Maxillary FPMs were 1.6 times more frequently affected than mandibular ones ($P < 0.001$), and the FPMs on the right side were 1.2 times more often affected than those on the left side ($P = 0.038$) (Fig. 3).

Table 1 Inter-observer O1–O3 variation, kappa (95 % CI)

	Observer	
Observer	O2	O3
O1	0.92 (0.89–0.94)	0.91 (0.89–0.93)
O2		0.99 (0.98–1.0)

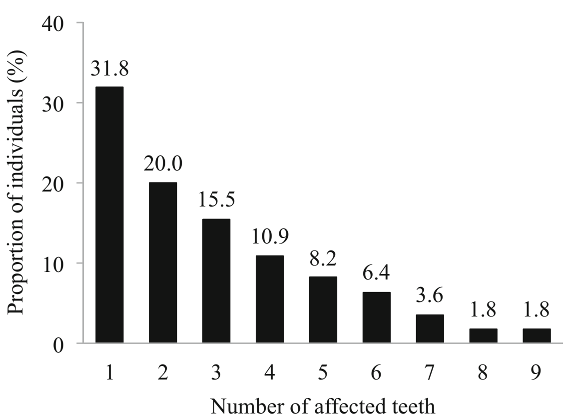

Fig. 2 Number of affected teeth among 110 individuals with MIH

Incisor involvement was recorded in 41.8 % of the participants with MIH; 32.8 % had one or two affected incisors, and 9.0 % had three to five incisors affected. Five was the maximum number of affected incisors in the same individual. The maxillary incisors were 2.5 times more often affected than the mandibular incisors ($P < 0.001$) (Fig. 3).

Canines were involved in 22.8 % of the individuals in the MIH group compared to 1.6 % of those without MIH ($P < 0.001$). All disturbances were localised in the incisal third of the canines, and in 10 out of 33 (30.3 %), the cusp tip was affected. The number of affected canines ranged from 1 to 2 among individuals with MIH, while none of the participants without MIH had more than one canine with enamel disturbance. The maxillary canines in the MIH group were 2.3 times more often affected than mandibular ones ($P = 0.019$) (Fig. 3). In participants without MIH, a total of 11 out of 2736 canines (0.4 %) were registered with enamel disturbances at the cusps of the crown.

The mean DMFS score was higher in participants who did not have MIH (6.2 surfaces) compared with those with MIH (5.6 surfaces) ($P = 0.331$).

Among the participants with MIH, 1.8 % of all FPMs had been extracted, 1.4 % (6 teeth) due to MIH and 0.4 % for other reasons. Among individuals without MIH, 0.3 % of all FPMs had been extracted. Altogether 201 FPMs were affected in the 110 individuals with MIH.

Opacities only were recorded in 54.0 % of these molars, while 24.3 % had PEB. In addition, atypical restorations were found in 18.8 % of the affected FPMs, and six teeth (3.0 %) had been extracted due to MIH (Fig. 4).

The buccal surfaces (78.6 %) were most often affected in FPMs, followed by the occlusal surfaces (39.3 %), while the lingual surfaces (27.9 %) were least frequently affected (Table 2). In the maxillary FPMs, the occlusal and lingual surfaces were more frequently affected compared with the lower FPMs (Table 2). More severe lesions (grade 2) were found in the mandibular FPMs compared with the maxillary FPMs, 37.1 and 59.1 %, respectively ($P = 0.002$) (Fig. 4).

In the affected incisors, the opacities or PEBs were found on the buccal surfaces. One exception was an individual who had palatal opacities in both maxillary central incisors and unaffected enamel on the buccal surfaces. In total, 91 affected incisors were registered and no incisor was extracted due to MIH. The proportion of PEBs and atypical fillings was higher in the maxillary incisors compared with the corresponding lower teeth (16.9 vs. 11.5 %; $P = 0.52$).

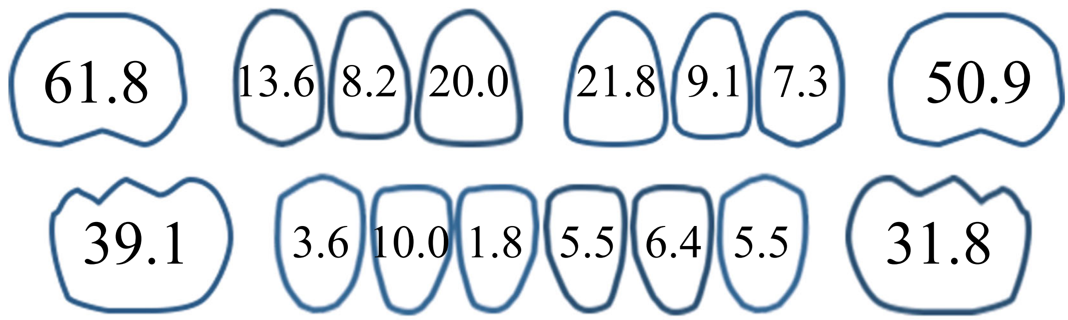

Fig. 3 Proportion (%) and distribution of the affected MIH teeth among 110 individuals with MIH

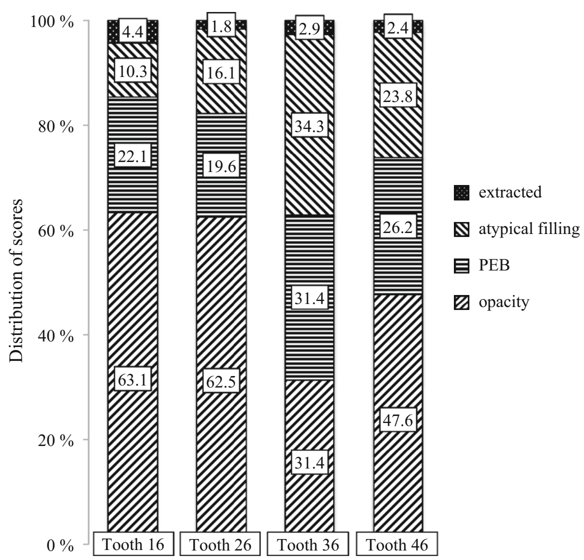

Fig. 4 The distribution (proportion) and severity of the 201 affected FPMs in 110 individuals with MIH

The central incisors in the maxilla were more often affected than the laterals, in contrast to the mandible where the laterals most frequently were involved (Fig. 3). Of the affected 33 canines in MIH group, no PEB was found in lower jaw, but 13.0 % had PEBs or atypical fillings in upper jaw.

Out of 110 participants with MIH, 11 cases (10.0 %) displayed bilaterally symmetrical distribution of enamel disturbances; the same teeth on both sides were affected. However, the severity varied between the corresponding teeth in the majority of these cases.

Discussion

The individuals reported on in the present study were older than in other epidemiological studies of MIH with the exception of that of Dietrich et al. (2003) who included 16-year-olds and 17-year-olds in their survey. The age of the included patients in the present study allowed the extent to which permanent canines were affected to be studied. Altogether 794 16-year-olds were included, and the prevalence of MIH was 13.9 %. Almost one-quarter of the MIH-affected individuals (22.8 %) had one or more canines with signs of MIH and significantly more frequent than among the non-affected individuals.

In Finland, Leppäniemi et al. (2001) reported a MIH prevalence of 19.3 %, while in Sweden, Koch et al. (1987) found values varying from 3.6 to 15.4 % depending on the age cohort included. Other Swedish studies reported prevalences of 18.4 % (Jälevik et al. 2001) and 16.0 % (Brogardh-Roth et al. 2011). However, in a Danish study a considerably higher prevalence (37.3 %) was found

Table 2 Distribution of enamel defects due to MIH on three index surfaces in affected FPMs

Tooth (*n*)	Tooth 16 (68)			Tooth 26 (56)			Tooth 36 (35)			Tooth 46 (42)		
Index surface	B	O	L	B	O	L	B	O	L	B	O	L
Number of affected surfaces	52	23	26	40	24	19	30	15	5	36	17	6
Grade 1: mild lesions (opacities)	43	7	13	30	11	6	10	7	1	17	5	3
Grade 2: severe lesions	9	16	13	10	13	13	20	8	4	19	12	3
PEB	4	9	8	5	6	8	10	2	3	12	2	0
Atypical restoration	2	4	2	4	6	4	9	5	0	6	9	2
Extracted		3			1			1			1	

PEB Posteruptive breakdown, *B* buccal, *O* occlusal, *L* lingual

(Wogelius et al. 2008). These reports from Nordic countries and international studies emphasise the fact that MIH prevalence varies considerably (Elfrink et al. 2015). The cause of the wide range in reported prevalence of MIH is not yet understood, but geographical variations (Wogelius et al. 2008; Petrou et al. 2013) as well as differences between age cohorts (Koch et al. 1987; Dietrich et al. 2003; Kukleva et al. 2008) have been suggested. Participation in the present study was high (92.9 %), which strengthens its internal validity.

Different diagnostic criteria, varying numbers of examiners and different types of examination (clinical examination vs. photograph evaluation) can lead to incomparable data. Most Scandinavian studies are based on clinical examinations (Alaluusua et al. 1996b; Jälevik et al. 2001; Leppäniemi et al. 2001; Wogelius et al. 2008), while Brogardh-Roth et al. (2011) used both clinical examinations and clinical photographs. In the present study, clinical photographs and the EAPD criteria (Lygidakis et al. 2010) were used. Only opacities greater than 1 mm were registered. In other Scandinavian studies, opacities smaller than 2 mm were excluded (Jälevik et al. 2001; Leppäniemi et al. 2001; Brogardh-Roth et al. 2011) or else the size of the defects was not a stipulated inclusion criterion (Koch et al. 1987).

Observer variation is a factor that has to be considered when comparing results from different studies (Kopans 2000). In the present study, these concerns have been addressed by using three observers who scored independently and a final decision was made by consensus agreement.

Clinical photographs, as a basis for MIH examinations, have been used in three studies by Elfrink et al. (2009, 2012, 2013). It has been shown that the sensitivity and specificity of photograph-based detection of deciduous molar hypomineralisation (DMH) using the adapted MIH criteria were high. The inter- and intra-observer reliabilities for DMH were good to excellent. The authors suggested that intra-oral photographs may be used in clinical practice and in large epidemiological studies (Elfrink et al. 2009).

The recorded difference in MIH prevalence between girls and boys (16.3 vs. 11.6 %) was close to statistical significance ($P = 0.054$). In previous MIH studies from Scandinavia (Leppäniemi et al. 2001; Wogelius et al. 2008), and in most international publications (Jasulaityte et al. 2007; Preusser et al. 2007; Martínez Gómez et al. 2012; Garcia-Margarit et al. 2013), no statistically significant gender difference had been found. A few studies reported that females were more frequently affected. Jeremias et al. (2013) found that the prevalences among girls and boys were 62 vs. 38 %, while Cho et al. (2008) showed a female-to-male ratio of 1.2:1.

In the present study, the mean number of affected teeth (canines not included) was 2.9 among individuals with MIH. This was somewhat lower than in other Scandinavian data, in which this number varied from 3.2 (Jälevik et al. 2001) to 3.6 teeth (Wogelius et al. 2008). The present study showed that FPMs were more frequently affected than incisors (Fig. 3), which is in line with previous reports (Lygidakis et al. 2008b; Kühnisch et al. 2014; Jankovic et al. 2014). The mean number of affected FPMs was 2.0, which corresponds well with other Scandinavian reports in which the numbers range from 1.5 to 2.5 teeth (Wogelius et al. 2008; Brogardh-Roth et al. 2011). The mean number of affected incisors was 0.9. This was considerably lower than the 2.2 teeth reported in a Greek study (Lygidakis et al. 2008b). In the present study, almost one quarter of the MIH-affected individuals had at least one affected canine in comparison with 1.6 % in the group without MIH ($P < 0.001$). There are only two reports mentioning MIH-affected permanent canines (Dietrich et al. 2003; Bhaskar and Hegde 2014), because the study populations are usually too young to have erupted canines. Bhaskar and Hegde (2014) showed that 27.3 % of MIH-affected children in India had hypomineralised canines and premolars, but did not report the types of defect or numbers of canines affected. The age of their study population ranged from 11 to 13 years. Dietrich et al. (2003) examined 2408 individuals aged 10–17 years and showed that 19.2 % of the individuals with MIH had opacities on the cusps of the canines. The present study showed that the maxillary canines were more than twice as often affected than those in the mandible and the opacity-to-PEB/atypical restorations ratio was 6.7:1. The lower canines showed only opacities; all PEB/atypical restorations occurred in maxillary canines.

The participants in the present study were older than in most other MIH studies (mean age 16.6 years), and affected teeth had been in occlusion for 5–10 years. Tooth wear and previous dental treatment could have masked the prevalence of MIH. This could lead to an underestimation of MIH, but this age group gave the opportunity to evaluate the permanent canines. However, the DMFS value was low in the MIH group and not statistically significantly different from the non-affected individuals. This suggests that it is unlikely that many restorations have masked enamel disturbances.

Our results showed that maxillary teeth in general were more often affected by MIH than mandibular ones, which is in accordance with most other studies (Leppäniemi et al. 2001; Preusser et al. 2007; Martínez Gómez et al. 2012). An exception is Parikh et al. (2012) who found that mandibular FPMs were statistically significantly more often affected than maxillary FPMs. In some papers, however, no such difference was reported (Jälevik et al. 2001; Chawla et al. 2008). The maxillary right FPM has previously been reported to be the most frequently affected tooth (Lygidakis et al. 2008a; Martínez Gómez et al. 2012) among patients with MIH, which is consistent with the finding in the present study.

In agreement with previous studies, we found that opacities were the most frequent enamel defect in MIH teeth (Jasulaityte et al. 2007; Muratbegovic et al. 2007; Wogelius et al. 2008; Soviero et al. 2009; da Costa-Silva et al. 2010; Ghanim et al. 2011; Allazzam et al. 2014). On the other hand, the frequency of PEB and atypical restorations in FPMs in the present study was 24.3 and 18.8 %, respectively. This was higher than reported in Denmark (8.4 vs. 7.8 %) (Wogelius et al. 2008), Germany (12.7 vs. 9.6 %) (Petrou et al. 2015) and Iraq (24.0 vs. 3.2 %) (Ghanim et al. 2011), but more in line with the report from Saudi Arabia (34.8 vs. 8.7 %) (Allazzam et al. 2014). The surface of some opacities may break down when the tooth has been exposed to the oral environment for some time, and this may explain the relatively high frequency of PEB in the present study.

One typical feature of MIH is the non-symmetrical appearance in the dentition. This clinical experience is supported by the present results. Only 11 cases (10.0 %) showed a symmetrical distribution of enamel disturbances, which means that the same tooth on both sides was affected. Furthermore, the severity of the lesions varied between the corresponding teeth in the majority of these cases. The non-symmetrical occurrence of the enamel lesions in most MIH-affected individuals could suggest that the insult causing defective enamel is of short duration and affects ameloblasts at a critical phase (Fearne et al. 2004).

An interesting finding in the present population was the relatively high frequency of enamel disturbances in the canines (Fig. 3). In the maxilla, the canines were more often affected than lateral incisors. In addition a higher frequency and severity of affected canines in the maxilla than the mandible were found. A similar observation was recorded for the maxillary incisors, which were more often and more severely affected than incisors in the mandible in the present study. This is in line with previous reports (Preusser et al. 2007; Kühnisch et al. 2015; Petrou et al. 2015).

Experienced researchers working through the EAPD recommend that the optimal age for the clinical examination of MIH is eight years, while second primary molars should be examined at the age of five years (Elfrink et al. 2015). This is probably one reason why recent studies mostly focus on FPMs, incisors and second primary molars. The present cross-sectional study illustrated a more complete picture of MIH in the permanent dentition since assessment of canines was included (Liversidge 2000). In future research, a longitudinal design including examination in the adolescent period is recommended (Jälevik 2010; Lygidakis et al. 2010; Kühnisch et al. 2014).

Occlusal and buccal surfaces were most commonly affected in FPMs, as well as the labial surface in incisors, also reported by Petrou et al. (2015). These surfaces have thicker enamel than the lingual/palatinal surfaces in FPMs (Lygidakis et al. 2010). The thicker the enamel, the longer the formation period, which increases the possibility of enamel disturbances (Lygidakis et al. 2010). Another interesting phenomenon of MIH is that the cervical third of the tooth usually is not affected (Jälevik and Noren 2000; Preusser et al. 2007), which might be related to the thin enamel in this area.

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