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ORIGINAL ARTICLE

Is there a relationship between hyperactivity/inattention symptoms and poor oral health? Results from the GINIplus and LISAplus study

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Abstract
Objectives A few clinical observations reported that children with attention deficit hyperactivity disorder (ADHD) have poor oral health compared to children without ADHD. However, evidence is not conclusive. We assess the association between hyperactivity/inattention and oral health in a population-based study.
Material and methods As part of the ongoing birth cohort studies German Infant Nutritional Intervention-plus (GINI-plus) and Influences of lifestyle-related factors on the immune

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system and the development of allergies in childhood-plus (LISAplus), 1,126 children at age 10 years (±10.2) from Munich (Germany) were included in the present analysis. During the dental examination, oral hygiene, non-cavitated and cavitated caries lesions, dental trauma, and enamel hypomineralization (EH) in the permanent dentition (MIH/1) were recorded. Children with a Molar-Incisor-Hypomineralization were subcategorized into those with EH on at least one first permanent molar (MIH/1A), and on at least one first permanent molar and permanent incisor (MIH/1B). Data on children's hyperactivity/inattention symptoms were collected by parent-reported Strength and Difficulties Questionnaire. Logistic regressions and zero-inflated Poisson regression models were applied adjusted for gender, parental education, parental income, and methylphenidate or atomoxetine medication.

Results Logistic regressions showed that non-cavitated caries lesions were positively related with the presence of hyperactivity/inattention (OR_{adj}=1.51,$CI_{95\%}$=1.08–2.11). When adjusted for parental background, an association showed between hyperactivity/inattention symptoms and MIH/1A but did not reach statistical significance (OR_{adj}= 1.59,$CI_{95\%}$=1.00–2.53).

Conclusions Children with borderline and abnormal values of hyperactivity/inattention symptoms showed more non-cavitated caries lesions. Severe levels of hyperactivity/inattention may contribute to a higher risk for MIH/1A in school age.

Clinical relevance Adequate dental preventive care for children with hyperactivity/inattention, especially from a low social background, is of importance for optimal caries prevention.

Keywords Hyperactivity · Inattention · ADHD · Oral health · Dental caries · Molar-Incisor-Hypomineralization

Introduction

Dental caries is one of the most prevalent chronic disorders in children. Although epidemiological studies have reported a decline in caries among children in Western Europe during the last decades [1], there is a remaining constant incidence rate and an increasing number of caries-affected teeth with increasing age, especially in lower socioeconomic groups, immigrants, and in children [2–4]. This increase is thought to be linked to the presence of caries risk factors, e.g., frequent intake of sugared drinks, inappropriate oral hygiene, and suboptimal fluoride supplementation [5].

Besides the decline of caries, it has become obvious that enamel hypomineralization in terms of molar-incisor-hypomineralization is prevalent in children [6–9]. Such enamel hypomineralizations (EH) can be diagnosed as demarcated opacities in enamel with or without surfaces disintegrations [8]. The loss of enamel leads to unprotected dentin and unexpectedly fast caries development can be seen in these teeth [9]. In cases where any enamel breakdowns affect the teeth—mostly first permanent molars—these teeth have to be restored. Furthermore, affected teeth can be very sensitive to a current of air, to cold and warmth, and mechanical stimuli (toothbrushing) and may create toothache shortly after eruption [10, 11].

The dental community also raises concerns about oral health in children with attention deficit/hyperactivity disorder (ADHD) [12, 13]. Since ADHD is characterized by symptoms of inattention, hyperactivity, and impulsivity to the extent that the symptoms impair the child's ability to function [14], it has been suggested that these children may be unable to perform regular routine activity like toothbrushing in an effective manner which may lead to improper oral hygiene practices [13, 15]. Furthermore, the diet and appetite of child with hyperactivity and inattention may be altered by medications that could contribute to an increased caries risk [12].

So far, only a few small case–control studies on the oral health of children with/without ADHD have been published [12, 13, 16–18]. These studies have not produced consistent results about caries frequency and experience. Two studies reported that children with ADHD have higher dental caries prevalence [16, 17], one study found higher non-cavitated caries lesions [12], and another study found higher dental caries experience in ADHD subjects to be explained by poor oral hygiene and increased consumption of sugary foods [13], whereas one study found no association between ADHD and dental caries or oral hygiene [18]. For example, a study of Blomqvist et al. [17] observed a significant higher dental caries prevalence in children with ADHD, but found no evidence for a poor oral hygiene in these children. The inconsistent findings may be partially explained by small sample sizes, confounding factors, or heterogeneity of the study populations, which makes interpretation of these studies difficult. Furthermore, no studies were conducted so far to investigate possible associations between EH/MIH and hyperactivity/inattention [19].

As far as we know, no previous studies have investigated hyperactivity/inattention symptoms in relation to caries and MIH on the basis of a large population-based sample. Therefore, our work aimed to associate hyperactivity/inattention symptoms with relevant dental health markers, e.g., oral hygiene, caries, MIH, and dental trauma in two large population-based birth cohorts at 10 years of age. It was hypothesized that there is a significant association between hyperactivity/inattention and the selected dental health indicators of the permanent dentition.

Material and methods

Study population

Data from two ongoing German birth cohort studies were combined for the present analysis. The German Infant Nutritional Intervention (GINI)plus study is a prospective birth cohort study that was initiated to investigate the influence of nutritional intervention during infancy as well as air pollution and genetics on allergy development. Details on study design, recruitment, and exclusion criteria have been described elsewhere [20, 21]. In brief, between September 1995 and June 1998, a total of 5,991 healthy full-term newborns were recruited in obstetric clinics in two regions of Germany (urban Munich and rural Wesel). All children were followed at the ages of 1, 2, 3, 4, 6, and 10 years to collect information on health outcomes and covariates, such as children's nutrition and other lifestyle factors. In the 10-year follow-up, 3,317 children (55.4 %) of the original study population participated. Loss to follow-up was associated with a lower level of parental education, a negative history of parental atopy, the absence of atopic diseases of the child during the first 2 years of life, and residency in Wesel.

The LISAplus study is a population-based birth cohort investigating "Influences of lifestyle-related factors on the immune system and the development of allergies in childhood". Details on study design are described elsewhere [22, 23]. In brief, between November 1997 and January 1999, a total of 3,097 newborns were recruited in the four German cities Munich, Leipzig, Wesel, and Bad Honnef. Data on the child's health were collected by repeated parental-completed questionnaires at regular time intervals during the first 10 years (0.5, 1, 1.5, 2, 4, 6, and 10 years of age).

Since dental examinations were only conducted in children from Munich, only their data were analyzed here. Children who received methylphenidate (Ritalin) or atomoxetine (Strattera) medication but had a normal value of hyperactivity/inattention were removed from our study sample (n=9). A complete set of data from the GINIplus and the LISAplus studies on dental examinations, and strengths and difficulties questionnaire data were available for 1,126 participants (577 male (51.2 %), 549 female (48.7 %)).

Approval by the local ethics committees (Bavarian General Medical Council) and written consent from participant's parents or guardians were obtained.

Measurement of hyperactivity/inattention

The Strengths & Difficulties Questionnaire (SDQ) is a brief behavioral screening questionnaire which can be filled out by parents and teachers or as self-report by children aged 11 years or older [24]. The German version of the SDQ has been found to be a valid and reliable screening instrument [25]. The SDQ comprises 25 items on psychological attributes divided into five subscales: (1) emotional symptoms; (2) conduct problems; (3) hyperactivity/inattention; (4) peer relationship problems; and (5) prosocial behavior. Each item is reported as 0 = "not true", 1 = "somewhat true", and 2 = "certainly true". The sum of four of the five subscale scores (the prosocial scale is excluded) yields a total difficulties score (range 0–40). The SDQ subscale hyperactivity/inattention ranges from 0 to 10 where higher scores denote more problems and was categorized according to the norms of the German SDQ version [25] into two groups indicating a "normal" vs. a "borderline" or "abnormal" amount of symptoms.

Oral health variables

Prior to the dental examination, each participant brushed their teeth. A halogen lamp to illuminate the oral cavity (Ri-Magic, Rudolf Riester GmbH, Jungingen, Germany), a blunt CPI probe (CP-11.5B6, Hu-Friedy, Chicago, IL, USA), a dental mirror, and cotton rolls for drying teeth were used to improve the clinical detection and diagnosis of plaque, sulcus bleeding/gingival inflammation, (non-cavitated) caries lesions as well as enamel hypomineralization. Oral hygiene was determined by recording the presence of plaque and gingivitis on Ramfjord teeth—16, 11, 26, 31, 36, and 46 [26, 27]. Non-cavitated caries lesions on all teeth and tooth surfaces were scored using the Universal Visual Scoring System ([28, 29]; http//:www.univiss.net). No x-rays were taken for caries diagnoses. The caries status and traumatized teeth were determined according to the WHO standard [27] as tooth and surface related DMF index for the permanent dentition (DMFT/S). In addition to the caries status, each child was carefully screened for EH according to the criteria of the European Academy of Pediatric Dentistry [8, 9]. In general, possible EH with a diameter <1 mm were not documented. Other enamel disturbances, e.g., hypoplastic defects, fluorosis (diffuse opacities), amelogenesis imperfecta and dentinogenesis imperfecta were distinguished from EH and were not scored. Children were grouped according to their distribution pattern of EH. At the beginning, all children with a minimum of one EH in the permanent dentition were categorized as group MIH/1; otherwise, subjects with no demarcated opacities were scored as free of EH. After this, we separated the children with at least one affected permanent molar to group MIH/1A [8–10]. Inside the MIH/1A-group, the distribution pattern was further analyzed so that children with EH on first permanent molars and incisors were additionally classified as MIH/1B [30].

Each child was investigated at the designated appointment by one of three calibrated dentists (JK, DM, and CN). Calibration training of the dentists was conducted in order to establish intra-rater and inter-rater reliability. The (un)weighted Kappa values for the intra- and inter-rater reliability were in a good to excellent order of magnitude (Intra-rater reliability of JK for occlusal/smooth surfaces: DMF 1.00/0.97, UniViss 0.98/0.90, enamel hypomineralization 0.75/0.93; Intra-rater reliability of DM: DMF 0.85/0.90, UniViSS 0.90/0.97, enamel hypomineralization 0.81/0.82; Intra-rater reliability of CN: DMF 0.86/0.90, UniViSS 0.90/0.81, enamel hypomineralization 0.85/1.00. Inter-rater reliability of JK for occlusal and smooth surfaces: DMF 1.00/0.99, UniViSS 0.93/0.97, enamel hypomineralization 0.87/0.96; Inter-rater reliability of DM: DMF 0.76/0.92, UniViSS 0.97/0.89, enamel hypomineralization 0.93/0.91; Inter-rater reliability of CN: CMF 0.86/0.92, UniViSS 0.89/0.93, enamel hypomineralization 0.72/0.95).

Statistical analysis

Mean and standard deviation (SD) were used to describe continuous variables. Student's t-tests, Wilcoxon test, and Chi-square test were used to compare several variables between subjects with normal vs. borderline or abnormal values of hyperactivity/inattention; a 0.05 level of significance was chosen. Kolmogorov Smirnov test and normal probability plots were used to test for normal distribution of oral health variables.

Logistic regression was applied to evaluate the effect of hyperactivity/inattention on the presence of a dichotomous coded oral health characteristic (code: 0 = "no", 1 = "yes").

Because there was little variability in continuous oral health data, e.g., for the number of teeth with caries (i.e., about 98 % of values are zero representing the caries-free children), it is quite difficult to obtain statistically or practically significant findings with them. Since the DMF index is a count variable, a Poisson regression should be used for count data. The zero-inflated Poisson (ZIP) regression, as compared with Poisson regression, is the most appropriate model for the dependent variable due to the overdispersion in the number of zero behavior problems [31, 32]. Therefore, we applied ZIP modeling to evaluate the effect of hyperactivity/inattention on several oral health markers. The ZIP uses a Logit model with binomial assumption to determine if an individual count outcome is from the always-zero or the not-always-zero group and a Poisson model for count data to model outcomes in the not-always-zero group [33]. Results of ZIP are presented as exp(beta) regression coefficients related to the log count model with their standard errors, and p values.

To account for potential confounding factors that might be associated with hyperactivity/inattention in children at age 10 years, gender, socioeconomic status of parents, body mass index, and methylphenidate or atomoxetine medication were selected based on the information from previous studies and were determined a priori. In the analysis, parental education was categorized based on the highest and completed grade in school and vocational training [34] from either parent. Household equivalent income was calculated by dividing the net household income per month, which was reported on an eleven-point scale ranging from less than €500 to more than €3,000, by the equivalence scale that considers family size based on the new Organization of Economic Cooperation and Development (OECD) guidelines [35]. Information on medication for hyperactivity/inattention symptoms was available from self-administered questionnaires filled in by the parents including the brand name or generic name of the medication. A sensitivity analysis was carried out whether children with hyperactivity/inattention drink more sugared drinks than children without hyperactivity/inattention. Children's drinking habits over the past year were measured by an 82-item food frequency questionnaire (FFQ) [36] administered to the parents. The parents were asked about the number of sugared drinks their children consumed by the time of day (breakfast, pauses, lunch, afternoon, dinner, evening, night), where total amount of sweet drinks was defined as sum of number of lemonade, coke, ice tea, sport drinks, and energy drinks consumed per day.

All computations were performed using the statistical software package SAS for Windows, version 9.1 (SAS Institute, Cary, North Carolina).

Results

Characteristics of the Munich GINIplus/LISAplus study sample are shown in Table 1. Subjects were assessed about 10 years after the baseline survey at birth. Mean age at dental examination was 10.2±0.2 years (range 9.8–11.8 years).

161 subjects (14.3 %) of the study population (n=1,126) showed a borderline or abnormal amount of hyperactivity/inattention. Males showed significantly more borderline or abnormal hyperactivity/inattention (p<0.001) than females.

No cavitated caries lesions and caries-associated restorations in the permanent dentition (DMF = 0) was found in 83.6 % (n=941) of the 10-year-olds. The mean (SD) caries experience among all children amounted to 0.30 (0.80) DMFT and 0.39 (1.22) DMFS (Table 2). Non-cavitated caries lesions were detected in 1.10 (1.47) permanent teeth and 1.45 (2.22) surfaces, respectively. Of all children, 33.8 % (n=381) had a minimum of one EH in the permanent dentition (MIH/1). Of all 10-year-olds, 13.7 % (n=154) had at least one affected permanent molar (MIH/1A). Nine percent (n=101) of children had EH on first permanent molars and incisors (MIH/1B).

Table 1 Characteristics of the study population in Munich at the 10-year follow-up

GINIplus and LISAplus (N=1,126)	n / mean	Percentage / SD
Study group		
GINI	678	60.2
LISA	448	40.0
Gender		
Male	577	51.2
Female	549	48.7
Age at examination (min: 9.77; max: 11.83)	10.2	0.2
Parental education[a]		
High	826	77.0
Medium	202	18.8
Low	45	4.2
Parental income[b]		
High	794	70.5
Medium	243	21.6
Low	89	7.9
SDQ hyperactivity/inattention[c]		
Normal	965	85.7
Borderline	60	5.3
Abnormal	101	9.0
Medication[d]		
None	866	100.0
Methylphenidate (Ritalin) or atomoxetine (Strattera)	16	1.6

[a] Educational status of parents defined as 1 = high, 2 = medium, 3 = low

[b] Income status of parents defined as 1 = high, 2 = medium, 3 = low

[c] Hyperactivity/ inattention defined as <6 normal value, 6 = borderline value, >6 abnormal value

[d] Children with medication treatment data (n=1,020)

There were no significant differences in DMFT/S index or in number of teeth/surfaces with caries (DT/DS) between subjects with a normal vs. borderline or abnormal value of hyperactivity/inattention (Table 2). Significantly, more children with borderline or abnormal value of hyperactivity/inattention had at least one non-cavitated caries lesion ($p<0.02$) compared to children with a normal value of hyperactivity/inattention. Children with borderline or abnormal value of hyperactivity/inattention also showed a higher number of teeth with non-cavitated lesions on tooth and tooth surfaces ($p<0.01$) than children with normal value of hyperactivity/inattention. No significant differences could be found in children with MIH/1, MIH/1A, or MIH/1B with regard to borderline/abnormal value of hyperactivity/inattention.

A total of 16 subjects (1.6 %) of the study population received methylphenidate or atomoxetine medication (Table 3). There was a high percentage of children (89.0 %) with borderline or abnormal values of hyperactivity/inattention who received no treatment. Sixteen (11.0 %) of the 145 subjects with borderline or abnormal values of hyperactivity/inattention received methylphenidate or atomoxetine medication. Children with hyperactivity/inattention had a higher consumption of sugared drinks than children without such symptoms.

The association of hyperactivity/inattention for dichotomous oral health variables was investigated by logistic regression models (Table 4). In unadjusted logistic regression analysis, children with borderline or abnormal values of hyperactivity/inattention had an increased likelihood (OR_{unadj}=1.51; $CI_{95\%}$=1.08–2.11) of being classified with non-cavitated caries lesions compared to children with normal values of hyperactivity/inattention. However, this association did not remain significant when controlled for gender and socioeconomic status, but became significant again when methylphenidate or atomoxetine medication was added as a confounder into the model (OR_{adj}=1.51, $CI_{95\%}$=1.02–2.23). When adjusted for parental background, an association showed between hyperactivity/inattention symptoms and MIH/1A, but did not reach statistical significance (OR_{adj}=1.59,$CI_{95\%}$=1.00–2.53). For none of the other oral health characteristics (caries, trauma), significant relationships were found with hyperactivity/inattention.

Unadjusted ZIP models showed that association between hyperactivity/inattention and number of teeth with gingivitis just failed statistical significance ($\exp(\beta)_{unadj}$ = 1.13, SE=0.06, p=0.05; Table 5). In the fully adjusted ZIP models, no other oral health variables, such as DMFT/S index, number of permanent teeth with caries, number of filled permanent teeth/surfaces (FT/FS), or number of teeth with plaque, were significantly related with hyperactivity/inattention.

Discussion

The present study indicates that borderline or abnormal values of hyperactivity/inattention were related with a higher frequency of non-cavitated caries lesions at the age of 10 years. There was an association with MIH/1A when controlled for parental background, albeit not statistically significant.

Our study provides some new information to clarify the current debate whether hyperactivity/intention symptoms are associated with caries in children. The association between hyperactivity/inattention with non-cavitated caries lesions in our study may be explained as a consequence of parental socioeconomic status but not with methylphenidate or atomoxetine medication. Low socioeconomic status of parents may increase risk for non-cavitated caries lesions in 10-year-olds. This suggests that the association of hyperactivity/inattention symptoms with caries is weaker than the social circumstances of the children. Our result that children

Table 2 Oral health by SDQ hyperactivity/inattention categories in the study population at 10-year follow-up

Oral health variables	SDQ hyperactivity/inattention categories						p value[a]
	Total (n=1,126)		Normal value (n=965)		Borderline or abnormal value (n=161)		
	N mean	% SD	n/N mean	% SD	n/N mean	% SD	
Number of index teeth with plaque (min:0 max:6)	2.06	1.82	2.02	1.82	2.35	1.83	0.0192
Number of index teeth with gingivitis (min:0 max:6)	1.83	2.04	1.80	2.02	2.04	2.10	0.2817
Number of traumatic injuries to permanent teeth	1.91	0.28	1.91	0.28	1.91	0.28	0.9291
At least one non-cavitated caries lesion							
No	581	51.6	512/965	53.1	69/161	42.9	0.0165
Yes	545	48.4	458/965	47.0	92/161	57.1	
Number of non-cavitated caries lesions on all teeth	1.10	1.47	1.05	1.42	1.40	1.70	0.0076
Number of non-cavitated carious tooth surfaces	1.45	2.22	1.36	2.10	1.96	2.80	0.0062
Caries or non-cavitated caries lesion							
No	516	45.8	457/965	46.9	63/161	39.1	0.0655
Yes	610	54.2	517/965	53.1	98/161	60.9	
DMFT	0.30	0.80	0.30	0.80	0.27	0.72	0.7627
DMFS	0.39	1.22	0.39	1.24	0.37	1.01	0.8051
Number of carious teeth (DT)							
0	1,101	97.8	943/965	97.7	158/161	98.1	0.2629
1	23	2.0	21/965	2.2	2/161	1.2	
2	2	0.2	1/965	0.1	1/161	0.6	
Number of carious surfaces (DS)							
0	1,101	97.8	943/965	97.7	158/161	98.1	0.2930
1	19	1.7	18/965	1.9	1/161	0.6	
2	4	0.4	3/965	0.3	1/161	0.6	
3	2	0.2	1/965	0.1	1/161	0.6	
Number of filled teeth (FT)	0.27	0.76	0.28	0.76	0.24	0.70	0.5600
Number of filled surfaces (FS)	0.36	1.16	0.37	1.19	0.30	0.89	0.5551
MIH/1A							
No	972	86.3	840/965	87.1	132/161	82.0	0.0837
Yes	154	13.7	125/965	12.9	29/161	14.2	
MIH/1B							
No	1,025	91.0	880/965	91.2	145/161	90.1	0.6424
Yes	101	9.0	85/965	8.8	16/161	9.9	
MIH/1							
No	745	66.2	643/965	66.7	102/161	63.4	0.4158
Yes	381	33.8	322/965	33.3	59/161	36.6	
Number of hypomineralized teeth	0.76	1.45	0.74	1.43	0.86	1.53	0.3529
Number of hypomineralized first permanent molars (min:0 max:4)	0.27	0.77	0.25	0.73	0.40	0.99	0.0673

[a] Chi^2 -test or Wilcoxon rank test

with hyperactivity/inattention have a higher intake of sugared drinks suggests an increased caries risk for these children. As a possible explanation of the high sugar food/hyperactivity relationship, parental educational style may be suggested [37–39].

The results of the present study regarding differences in caries dependent from socioeconomic status is consistent with considerable evidence worldwide that associate socioeconomic disadvantages with the incidence and severity of childhood dental caries prevalence [40–43]. Even within a single country, disparities by social position exist in large part because of differences in diet, fluoride use, and social empowerment [42]. An ecological study [43] using oral disease data from World Health Organization databases found that socioeconomic background variables alone accounted for approximately 50 % of the differences in the prevalence of dental caries at 12 years of age.

Table 3 Medication and consumption of sugared drinks by SDQ hyperactivity/inattention categories in the study population at 10-year follow-up

Medication	SDQ hyperactivity/ inattention categories						p value[a]
	Total (n=1,011)		Normal value (n=965)		Borderline or abnormal value (n=145)		
	n/N mean	% SD	n/N mean	% SD	n/N mean	% SD	
No medication	995/1,011	98.4	866/866	99.0	129/161	89.0	<0.0001
methylphenidate (Ritalin) or atomoxetine (Strattera)	16/1,011	1.6	0	0	16/161	11.0	
Average daily consumption of sugared drinks[b]	6.34	3.38	6.17	3.28	7.37	3.82	0.0001

[a] Chi^2 -test or t-test

[b] Sensitivity analysis: Children with food frequency questionnaire data (n=982)

We found more non-cavitated caries lesions in children with borderline/abnormal values of hyperactivity/inattention in unadjusted analyses. This is in line with a case–control study [12] which found that children with a Diagnostic and Statistical Manual of Mental Disorders fourth edition (DSM-IV) diagnosis of ADHD had more non-cavitated caries lesions at age 6–10 years, but not with another case–control study of children with DSM-IV diagnosis of ADHD [17] at the age of 11 years. These inconsistent results may at least partly be due to small sample sizes or that we used a broader construct to classify children with hyperactivity/inattention than the definitions used in these studies. Another plausible explanation is the different age of the children investigated in these studies. As the children in our study were 10 years of age, they probably had mainly newly erupted teeth, and the non-cavitated lesions had not yet become cavitated. With regard to DMFT or DMFS scores, results of our unadjusted analyses agree with two case–control studies that found no statistical significant differences in dmfs and DMFS scores in children medicated for ADHD at the age of 7 [18], and in children treated for ADHD in an outpatient psychiatry department with/without medication at the age of 8 years [13]. Our results are not in line with results from a case–control study which reports a significantly higher DMFS and decayed surfaces (DS) in permanent teeth in children with a DSM-IV diagnosis of ADHD at the age of 11 years compared to controls [17]. Since analyses of that study were based on children who fulfilled DSM-IV criteria for ADHD, it may be the case that differences in results between studies may be due the use of hyperactivity/inattention symptoms in our study. Our results also differ from Broadbent et al. [16] who found children with ADHD had nearly 12 times the odds of having a high DMFT score than children who did not have ADHD. Since this study used a matched case–control design according to the DMFT score instead of ADHD criteria, interpretation of their findings may be limited.

With respect to oral hygiene characteristics, we found no difference in teeth with plaque between the groups, which is in agreement with Bimstein et al. [18], but not with Chandra et al. [13].

Table 4 SDQ hyperactivity/inattention categories as predictor of oral health characteristics (binary outcome) at age 10 years

Oral health variables	Unadjusted model[a]			Adjusted model[b]			Adjusted model[c]		
	OR	$CI_{95\%}$	p	OR	$CI_{95\%}$	p	OR	$CI_{95\%}$	p
Non-cavitated caries lesions	1.51	1.08–2.11	0.0170	1.37	0.96–1.96	0.0805	1.51	1.02–2.23	0.0388
Caries or non-cavitated caries lesions	1.38	0.98–1.94	0.0662	1.22	0.85–1.74	0.2778	1.26	0.85–1.86	0.2543
Caries in permanent teeth	0.93	0.58–1.46	0.7387	0.86	0.53–1.39	0.5288	0.74	0.42–1.30	0.2874
MIH/1A	1.48	0.95–2.30	0.0853	1.59	1.00–2.53	0.0505	1.08	0.62–1.89	0.7742
MIH/1B	1.14	0.65–2.00	0.6426	1.15	0.64–2.08	0.6351	0.53	0.22–1.25	0.1447
MIH/1	1.16	0.82–1.64	0.4160	1.20	0.83–1.72	0.3353	1.00	0.66–1.50	0.9890
Trauma in permanent teeth	0.97	0.54–1.76	0.9294	1.02	0.56–1.88	0.9415	1.12	0.58–2.15	0.7376

[a] Odds ratios (OR) of hyperactivity/inattention categories on presence of oral health characteristics (defined as 0 = no, 1 = yes) are estimated by logistic regression

[b] Adjusted for gender, parental education, and parental income

[c] Model 2 and, in addition, methylphenidate and atomoxetine medication

Table 5 SDQ hyperactivity/inattention categories as predictor for oral health characteristics (continuous variables) at age 10 years of age

Oral health variables	Unadjusted model[a]			Adjusted model[b]			Adjusted model[c]		
	exp(β)	SE	p	exp(β)	SE	p	exp(β)	SE	p
Number of index teeth with plaque	1.10	0.06	0.1349	1.05	0.07	0.4618	1.05	0.07	0.4912
Number of index teeth with gingivitis	1.13	0.06	0.0486	1.11	0.07	0.1469	1.11	0.08	0.1828
Number of permanent teeth with initial caries lesions	1.13	0.09	0.1635	1.10	0.09	0.2923	1.10	0.10	0.3235
DMFS	0.98	0.17	0.9038	0.99	0.17	0.9736	0.96	0.21	0.8578
DMFT	0.94	0.23	0.7789	0.88	0.24	0.6015	1.09	0.27	0.7449
Number of permanent teeth with caries	6.76	1.38	0.1658	5.97	1.35	0.1857	4.03	1.02	0.6348
Number of hypomineralized permanent teeth	1.08	0.11	0.4363	1.15	0.12	0.2268	0.93	0.15	0.6335
Number of hypomineralized first permanent molars	1.28	0.18	0.1575	1.33	0.18	0.1198	1.36	0.22	0.1568

[a] Exp (*β*) is the regression estimate of hyperactivity/inattention categories for the respective outcome (oral health characteristics) in a zero-inflated Poisson regression model (ZIP)

[b] Adjusted for gender, parental education, parental income

[c] Model 2 and in addition methylphenidate and atomoxetine medication

In our study, we found a significant association of hyperactivity/inattention and MIH diagnosis at the age of 10 years when controlled for parental social background. So far, there is no previous study available that investigated the relationship between EH or MIH and later hyperactivity/inattention symptoms. Since the relationship between hyperactivity/inattention and MIH attenuated largely when controlled for ADHD medication, it might be the case that systemic ADHD medication is an effect modifier of this relationship. However, due to our cross-sectional design, we are unable to address temporal relationships or causal chains. One interpretation of this result would be that the ADHD medication reduces symptoms of hyperactivity, impulsivity, and inattention, and that this reduction of symptoms might improve oral hygiene practices of these children. It is also possible that the MIH/hyperactivity relationship is coincidental. Other speculations would be that there are unknown common grounds between MIH/hyperactivity, or that improper cleaning is responsible for this relationship, or a combination of these factors. Thus, it is suggested to examine whether such an association exists in future studies. Future MIH studies should also consider systemic medications as possible etiological factor for MIH.

To our knowledge, this is the first population-based study to examine oral health as assessed by dental examination and hyperactivity/inattention symptoms in school age. Our study has a number of strengths. Importantly, we were able to control for a variety of potential confounders, including demographic factors and methylphenidate or atomoxetine medication.

We measured oral health characteristics by a valid and precise clinical examination with good intra-rater and inter-rater reliability. Our results are based on data of a population-based birth cohort in Munich. To exclude influence by prematurity, perinatal diseases, and antibiotics, we included only healthy newborns. We used a standardized and well validated, brief behavioral screening questionnaire (SDQ) which has been especially developed for use in epidemiological studies. Unlike previous studies using different ADHD definitions as study inclusion criteria, our definition of hyperactivity/inattention symptoms refers to subjects with a more severe amount of hyperactivity/inattention (85th percentile). However, although the SDQ has been found to have good validity for the main child psychiatric conditions including hyperactivity–inattention [44], this does not necessarily mean that the SDQ identifies a clinical diagnosis of ADHD specifically. Thus, an under- or overestimation of the hyperactivity/non-cavitated lesions relationship is possible.

A limitation of our study is that we could include only children whose parents consented for the clinical examination of their children. This may have resulted in a potential bias. In addition, the majority of parents in our sample were highly educated, which reflects the metropolitan area of Munich with a relatively high quality of life, high costs of living, low unemployment and crime rates, but also the fact that better educated parents more often agreed to the research project and showed less drop out over the 10 years compared to parents with a lower level of education. Since we adjusted logistic regressions and ZIP models for socioeconomic status, we likely eliminated group-specific drop out due to different socio-demographical background of parents. In fact, in the present study, we could demonstrate that differences in parental socioeconomic status were associated with differences in oral health. Due to the small sample size of children with borderline and abnormal hyperactivity, we may not have had enough power to detect differences between in several oral health characteristics. In addition, prematurely born children were excluded from the study, and we might have lost some children with hyperactivity/inattention, as prematurity is a risk for ADHD. Another source of possible under-reporting is that we had to rely on the information provided by the parents. It may be more meaningful to make use of a questionnaire with children and teachers as well to confirm the status of children's psychopathology. However, results on SDQ criterion validity showed that total difficulties reported by mothers could discriminate significantly between children attending psychiatric clinics versus attending a dental clinic [24, 45]. Although SDQ scales were not specifically based on the DSM or international classification of diseases (ICD) diagnostic criteria, the convergent designation of a scale as hyperactivity/inattention implies links to the diagnostic category of ADHD [46]. However, about 1 % of children with normal values of hyperactivity/inattention according to the SDQ norms received methylphenidate or atomoxetine medication

Conclusions

Non-cavitated caries lesions were significantly related with hyperactivity/inattention symptoms. However, our findings further indicate that parental socioeconomic status influences the caries and hyperactivity/inattention relationship. Therefore, adequate dental preventive care for children with hyperactivity/inattention, especially from a low social background, seems to be of importance for optimal caries prevention. In addition, high levels of hyperactivity–inattention symptoms were found to be a possible risk factor for MIH/1A diagnosis in the investigated 10-year-olds. The dental community may pay attention to this observation as the etiology of MIH is remaining unclear so far.

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Conflict of interest The authors declare that they have no conflict of interest.

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