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ORIGINAL ARTICLE

Association between age at asthma diagnosis and tooth loss

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ABSTRACT

Objectives: This study aimed to investigate the association between age at asthma diagnosis and tooth loss due to caries using data obtained from the Korean National Health and Nutrition Examination Survey.

Materials and methods: A complex sample multivariable linear regression was used, and the results were analysed. Age at diagnosis and the number of teeth lost were set as independent and dependent variables, respectively. Among the total 65,973 subjects, 10,056 aged <12 years and 11,714 with missing values in dependent and independent variables were excluded. Asthmatic subjects were divided into the following age groups based on the age at diagnosis: 0–6 years, 7–12 years, 13–18 years, 19–28 years, and 29–64 years. In each analysis, the calibration was performed by adding covariates to each model.

Results: Compared with the no asthma group ($\beta = 0$), the values of β in asthmatic subjects belonging to the age groups 0–6 years ($\beta = 0.794$, 0.521, 0.560) and 7–12 years ($\beta = 0.527$, 0.407, 0.437) were high in all models.

Conclusions: Our findings revealed significant increase in tooth loss due to caries after early asthma diagnosis at 0–6 years ($\beta = 0.560$, $p < .001$) and 7–12 years ($\beta = 0.437$, $p < .001$). Clinicians need to shift their perception of dental risks in young asthmatic patients and provide active oral health care to them.

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Introduction

Asthma prevalence has demonstrated increasing trend due to environmental pollution. Increase in traffic-related air pollution owing to increase in the amount of traffic has contributed to the increase in the prevalence allergic diseases in children [1]. According to the latest taxonomy, not all cases of asthma are allergy related; however, in most cases, it presents as a chronic allergic disease characterized by airway inflammation and bronchial constriction [2,3]. Asthma is a common disease similar to other allergic conditions, such as allergic rhinitis and atopic dermatitis, and appears in childhood [4]. Asthma prevalence is high in children and adolescents and tends to decrease in adults. However, it reappears during old age and deteriorates the quality of life of the patients.

Asthma continues to be a major public health concern worldwide, with a global prevalence of 4.3% (range, 0.2–21.0%) in adults [5]. This global prevalence is showing an upward trend due to factors, such as increase in the amount of traffic leading to increased air pollution [6]. Asthma, unlike other diseases, has a high morbidity rate at a young age but a low mortality rate. Once affected, the patient is likely to suffer from recurrence and symptom aggravation; thus, researchers have become increasingly aware of the fact that asthma is one of the risk factors for dental caries [7–11].

Asthma has diverse phenotypes, and its treatment method varies according to its phenotype. As shown in Figure 1, asthma is diagnosed in various ways depending on the cause of the condition and the timing of diagnosis [3]. It is desirable to apply a variety of therapeutic agents according to the disease progression; the steps for application have been revised and provided in a set of guidelines called GINA (Global Initiative for Asthma) [12].

Numerous reports on the adverse effects of drugs used to treat asthma are available. It has been suggested that a decreased level of bone marrow density due to the long-term use of steroids is one of the major factors leading to osteoporosis in elderly women, especially in smokers [13]. The drugs used for treating asthma are not metabolized in the liver but are directly applied to the oropharynx. Reports on local complications, such as oropharyngeal candidiasis, laryngeal weakness, choking, tooth decay, speechlessness, taste decrease, tongue burning and tongue abrasion, have been published; therefore, additional management strategies are required in the field of dentistry [13,14]. Various types of drugs, especially tablets, used for treating asthma pose as major risk factors for dental caries development [15].

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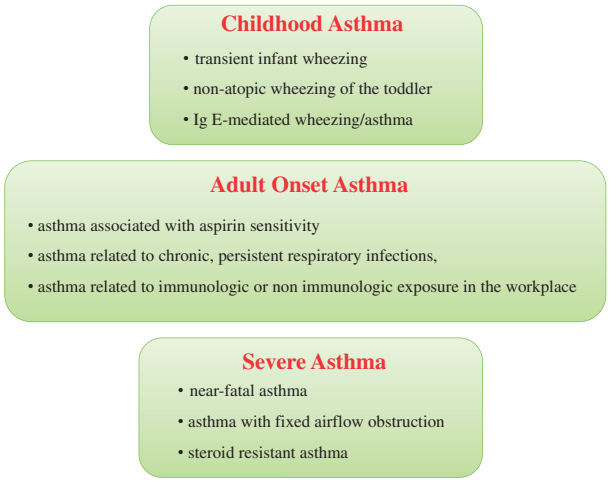

Figure 1. Diagnostic classification of asthma.

Researchers have become increasingly aware that asthma is one of the major risk factors for dental caries [8–11,16–19]. It has been accepted that the drugs used to treat asthma induce bronchial relaxation and react with the β adrenoreceptor agonist, which influences salivary gland function; β2 adrenoreceptor agonists alter the secretion and components of the saliva, thereby increasing the risk of dental caries development [20]. A meta-analysis of the association between asthma and the risk of dental caries development has revealed decreased secretion rates and composition changes in saliva as the major causes following the persistent use of anti-asthma drugs [21]. Other studies have also shown that reduced saliva secretion caused by asthma medication is a reliable risk factor [11]. However, these drugs did not act as direct risk factors when combined with adequate fluoride usage and regular dental care [22].

It is estimated that asthma diagnosis at an early age increases the risk of dental caries development. Some report has suggested no difference in periodontal health between children with mild asthma and those without [2]. However, many reports have suggested a close association between asthma and dental caries [16,23,24]. It has been proposed that asthma and diabetes are the major diseases that must be managed to prevent early childhood caries (ECC) [25]. It has long been recognized that the occurrence of ECC is closely related to the high rates of caries in adults, thus indicating that the management of severe caries in adults must be initiated during childhood [26]. And this association was confirmed through a systematic review and meta-analysis of the positive association between asthma and dental caries [21].

Asthma diagnosis during childhood is considered to increase the risk of caries development. It has been reported that asthma in children aged 4–6 years is a significant risk factor for the occurrence of enamel opacities and hypoplasia [27]. It is also known that teenage asthmatic patients show significant trends with regard to decreased salivary rate, increased gingival bleeding, and low plaque pH, which were mainly responsible for the early development of dental caries, gingival inflammations, and xerostomia [11,28].

Early tooth loss due to severe dental caries has been considered to have an adverse effect on the quality of life. Many studies have noted that socio-economic factors are the major causes of ECC, enamel hypoplasia, and severe caries in young adults [27,29–31]. This study intended to investigate asthma as a cause of severe caries in adolescents and to analyse its association with tooth loss, which is the most severe complication related to caries. Specifically, this study aimed to investigate the association between age at asthma diagnosis and tooth loss using the Korean National Health and Nutrition Examination Survey (KNHANES) data on patients with tooth loss [32].

Materials and methods

Data collection

KNHANES is a designed sample survey with target population in South Korea. It is produced and administered by the Korea Centers for Disease Control and Prevention based on Article 16 of the National Health Promotion Act. The government-designated statistics (approval no. 117002) were created based on Article 17 of the statistical law. It has been administered every 3 years since 1998, and the collected public health data has been sent to international organizations, such as the WHO and the OECD. The survey contains a variety of health-related questions. A field survey team comprising public health dentists, otorhinolaryngology major residents, nurses and health care investigators conducts the survey at the mobile examination centre.

The examination survey involves body measurements, blood pressure data, clinical examinations, oral examinations and otorhinolaryngological examinations. The health questionnaire examines factors, such as diseases, smoking status, alcohol consumption and obesity, through an interview and self-reported questionnaires. KNHANES is a publicly available dataset dependent on the informed consent of all subjects under the approval of the National Statistical Office and the Ethics Review Board of the Disease Control Division.

Research subjects and selection criteria

The fourth (2007–2009), fifth (2010–2012) and sixth (2013–2014) KNHANES datasets were used for analysis in this study. The sampling protocol for KNHANES was designed to include a complex, stratified, multistage probability-cluster survey of a representative sample of the non-institutionalized civilian population in Korea. The target population of the survey included all non-institutionalized civilian Korean individuals aged $\geq$1 year. The survey used stratified multistage probability sampling units based on geographic area, gender and age, which were determined based on the household registries of the National Census Registry; this is the most recent 5-year national census in Korea. Each year, 200 primary sampling units are selected across Korea, and the final sample set for KNHANES includes approximately 4600 households. A detailed description of the sampling can be found in the KNHANES report [32]. Among the total 65,973 subjects, 10,056 aged $<$12 years and 11,714 with missing values in the

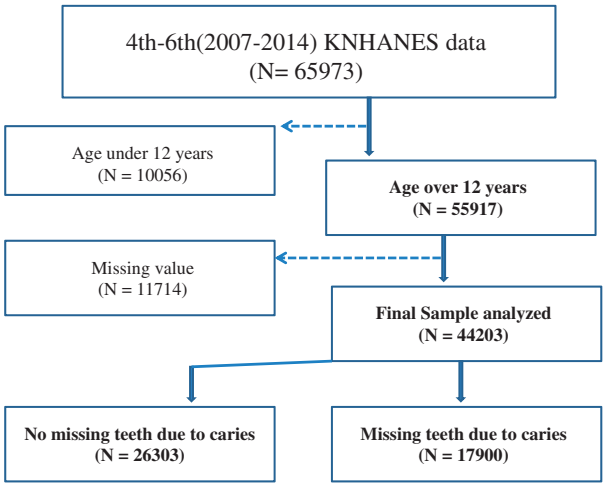

Figure 2. Overview of the study samples.

dependent and independent variables were excluded, and the final number of study subjects was 44,203 (Figure 2).

Dental records (whether the teeth were sound, decayed, filled with caries, filled without caries, sealed and unerupted) for each tooth surface (buccal, distal, occlusal, mesial and lingual) were used. We also used the 'treatment-needed' results of each tooth, including the need for crown treatment, root canal treatment, filling treatment and extraction treatment records. The dental records were entered and maintained by trained dentists using standardized guidelines. The records of patients with missing teeth included items regarding the causes of tooth loss. Wisdom teeth were excluded from this study because they were often intentionally extracted during orthodontic treatment and did not erupt in many cases.

In this study, we assumed that when the age at asthma diagnosis is lower, the loss of teeth due to caries is greater. Permanent teeth begin erupting at 6 years of age, which is when caries development occurs. Permanent dentition is completed at approximately 12 years of age; tooth loss due to caries is known to increase with age. To analyse dental caries development and tooth loss after the completion of permanent dentition, the subjects in this study were limited to those aged $\geq$12 years. As age increases, the occurrence of caries and tooth loss also increases due to numerous factors; therefore, the effects of age and other parameters were considered.

Dependent variable

The number of teeth removed because of caries was defined as the number of permanent teeth lost due to caries. Because wisdom teeth were excluded from this study, the number of permanent teeth lost due to caries was theoretically 0–28. The mean number of permanent teeth lost due to caries was 2.21, and the standard deviation was 4.46 for all 44,203 subjects (Figure 2).

Independent variable

The age at asthma diagnosis was analysed; 2.86% of the total subjects were diagnosed with asthma, which is lower than the global average of 4.27% [5]. The condition was diagnosed in the subjects aged $\geq$0 years. Considering the eruption timings of permanent teeth, subjects diagnosed with asthma were divided into the following age groups based on the age at diagnosis: 0–6 years, 7–12 years, 13–18 years, 19–28 years and 29–64 years (Table 1).

Covariates

The age and body mass index (BMI) of the subjects were applied as continuous covariates to the multivariable linear regression. In addition, gender, smoking status, alcohol consumption, household income and self-reported oral health status of the subjects were applied as categorical variable factors. In terms of the smoking status, subjects were divided into present smokers and non-smokers. Alcohol consumption was calculated by multiplying the frequency of alcohol consumption, the quantity of intake and the alcohol content percentage according to the type of alcohol and was divided into three levels: no drinking (0 g alcohol/day), mild-to-moderate drinking ($<$30.0 g alcohol/day) and heavy drinking ($\geq$30.0 g alcohol/day). Household income was adjusted for the number of household members and divided into four levels according to the quartile. Similarly, BMI was divided into four levels according to the quartile. The self-reported oral health status of the subjects refers to their subjective judgment about their own oral health; this information was divided into the following two categories: good and bad.

Methods of analysis

Individual weighted factors were used, and the complex sampling design of the survey was considered to obtain variances. The multivariable linear regression was applied to examine the associations between the age at asthma diagnosis and the number of teeth lost that was adjusted for the effects of the covariates in the stepwise models. Statistical analyses were performed using SPSS Statistics version 21.0 (IBM Corporation, Armonk, NY, USA). The multivariable linear regression was used because the variables were quantitative, enabling the use of complex samples of the internal menu in the SPSS program for the analysis.

Results

The means and standard deviations of the number of permanent teeth lost due to caries in the study subjects are presented in Table 1. Our results showed that asthmatic patients are diagnosed at a young age, following which the high diagnostic rates temporarily reduce only to gradually increase again with age.

Figure 3 shows the comparison of the association between the age at asthma diagnosis and tooth loss by age group. As the no asthma group showed, the loss of teeth related to asthma naturally increased with age. It should be noted that this group (0–6 years of age) comprised subjects who had already lost several teeth by 20–30 years of age. With increase in age, a large variation in tooth loss was

Table 1. Univariate association of the number of missing teeth due to caries with age of asthma diagnosis, demographic variables and health-related variables.

Characteristics	Levels of categorical variables	Unweighted *N*	Proportion (%)	The number of missing teeth due to caries (mean ± SD)	*p* Value
Total		44,203	100.00	2.21 ± 4.46	
Independent variables					
Age of asthma diagnosis	No asthma	42,939	97.14	2.19 ± 4.44	<.001
	0–6 years	208	0.47	0.25 ± 0.95	
	7–12 years	132	0.30	0.48 ± 1.90	
	13–18 years	39	0.09	0.90 ± 3.02	
	19–28 years	116	0.26	1.93 ± 4.62	
	29–64 years	769	1.74	3.85 ± 5.74	
Agea	12–19 years	4415	9.99	0.02 ± 0.20	<.001
	20–29 years	4572	10.34	0.23 ± 0.81	
	30–39 years	7570	17.13	0.43 ± 1.07	
	40–49 years	7519	17.01	0.86 ± 1.78	
	50–59 years	7429	16.81	2.06 ± 3.34	
	60–69 years	6729	15.22	4.27 ± 5.57	
	over 69 years	5969	13.50	7.13 ± 7.13	
Gender	Male	19,149	43.32	1.93 ± 4.11	<.001
	Female	25,054	56.68	2.41 ± 4.71	
Smoking	No	33,169	75.04	2.17 ± 4.43	.002
	Yes	11,034	24.96	2.32 ± 4.55	
Alcohol consumption	No drinking (0 g alcohol/d)	14,713	33.29	3.11 ± 5.47	<.001
	Mild to moderate (<30.0 g alcohol/d)	26,721	60.45	1.79 ± 3.85	
	Heavy (≥30.0 g alcohol/d)	2769	6.26	1.40 ± 3.11	
House income(HI)	< 25 percentile	8517	19.27	4.82 ± 6.43	<.001
	25 ≤ HI < 50 percentile	11,217	25.38	2.30 ± 4.41	
	50 ≤ HI < 75 percentile	12,161	27.51	1.37 ± 3.21	
	≥75 percentile	12,308	27.84	1.13 ± 2.90	
Body Mass Index(B)a	<25 percentile (<20.97 kg/m^2)	11,019	24.93	1.83 ± 4.44	<.001
	25 ≤ B < 50 percentile (20.97 ≤ B < 23.22 kg/m^2)	11,078	25.06	2.23 ± 4.55	
	50 ≤ B < 75 percentile (23.22 ≤ B < 25.53 kg/m^2)	10,991	24.86	2.39 ± 4.46	
	≥75 percentile (≥25.53 kg/m^2)	11,053	25.01	2.38 ± 4.38	
Self-reported oral health status	Good	24,293	54.96	1.56 ± 3.91	<.001
	Bad	19,910	45.04	2.99 ± 4.94	

p Values are obtained from one-way ANOVA or independent *t*-test for categorical variables.
[a]Age and body mass index are continuous variables and adjusted into general linear model as covariates.

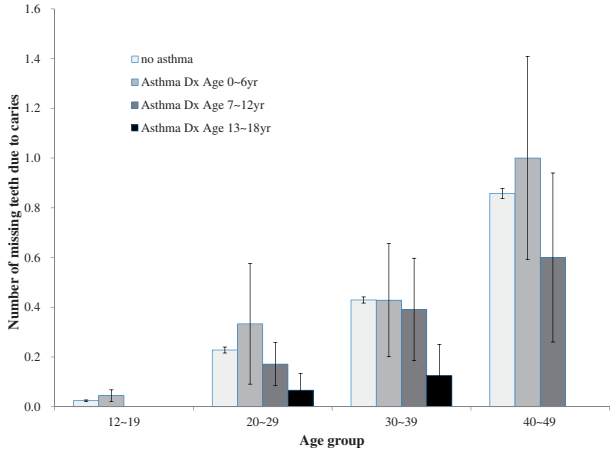

Figure 3. Comparison of the association between the age at asthma diagnosis and tooth loss by age group.

noted in this group compared with the other groups. Although this variation was not statistically significant, it may be attributed to the notion that an individual may experience severe tooth loss due to caries if he or she is diagnosed with asthma at a young age.

Table 2 shows the results of a stepwise regression analysis demonstrating the association of the number of teeth lost due to caries and the age at asthma diagnosis. Models 1, 2 and 3 with added covariates revealed that lower age at diagnosis is associated with more loss of permanent teeth due to caries. Compared with the no asthma group ($\beta = 0$), the values of β in the age groups 0–6 years ($\beta = 0.794$, 0.521, 0.560) and 7–12 years ($\beta = 0.527$, 0.407, 0.437) were significant in all models (1, 2 and 3). Asthma diagnosis in other age groups (>12 years) was not significant.

Discussion

This study reaffirmed that subjects who were diagnosed with asthma at a young age (0–12 years) had significantly more tooth loss due to caries than that in subjects in the other groups. An analysis of the 2007–2014 KNHANES data showed significant tooth loss due to dental caries in patients who were diagnosed with asthma before 12 years of age. Previous studies have reported associations with dental caries in asthmatics of various ages, such as before 3 years, 3–6 years, 6–10 years, 10–14 years and 12–16 years [11,19,33]. In this study, we divided the dentition phases into 0–6 years of age (deciduous dentition), 7–12 years of age (mixed dentition), adolescents and young adults. We confirmed that asthma diagnosis in patients aged ≤ 12 years showed a significant correlation ($p < .01$, 0–6 years; $p < .01$, 7–12 years) with tooth loss due to caries.

Because tooth loss was cumulative with age, it was necessary to compare the age groups. As this study aimed to examine the causes of tooth loss besides natural causes, the number of teeth lost was calculated by crossing the age at asthma diagnosis and the age groups in order to find an association. Furthermore, to avoid confusion, only the

Table 2. Multivariable association of the number of missing teeth due to caries with age of asthma diagnosis adjusted for covariates by stepwise multivariable linear regression (unweighted $N = 44{,}203$).

Independent variables	Levels of categorical variables	Model 1		Model 2		Model 3	
		β (95% CI)	p Value	β (95% CI)	p Value	β (95% CI)	p Value
Age of asthma diagnosis	No asthma	0.000 (reference)		0.000 (reference)		0.000 (reference)	
	0–6 years	0.794 (0.626, 0.961)	<.001*	0.521 (0.374, 0.669)	<.001*	0.560 (0.415, 0.704)	<.001*
	7–12 years	0.527 (0.300, 0.755)	<.001*	0.407 (0.159, 0.655)	.001*	0.437 (0.182, 0.691)	<.001*
	13–18 years	0.365 (0.007, 0.723)	.046*	0.379 (0.007, 0.751)	.046*	0.268 (–0.124, 0.660)	.180
	19–28 years	−0.067 (–0.486, 0.351)	.753	–0.055 (–0.484, 0.374)	.802	–0.064 (–0.485, 0.357)	.766
	29–64 years	0.389 (–0.008, 0.785)	.055	0.266 (−0.129, 0.660)	.187	0.264 (–0.128, 0.656)	.186
	–	–	–	–	–	–	–
Age	(Year)	0.103 (0.100, 0.107)	<.001*	0.095 (0.092, 0.098)	<.001*	0.095 (0.092, 0.098)	<.001*
Gender	Male	−0.332 (−0.391, −0.273)	<.001*	−0.258 (−0.322, −0.194)	<.001*	−0.203 (−0.268, −0.138)	<.001*
	Female	0.000 (reference)	–	0.000 (reference)	–	0.000 (reference)	–
Smoking	No	–	–	−0.240 (−0.323, −0.158)	<.001*	−0.161 (−0.245, −0.077)	<.001*
	Yes	–	–	0.000 (reference)	–	0.000 (reference)	–
Alcohol consumption	No drinking (0 g alcohol/d)	–	–	0.853 (0.728, 0.979)	<.001*	0.821 (0.696, 0.946)	<.001*
	Mild to moderate (<30.0 g alcohol/d)	–	–	0.214 (0.120, 0.309)	<.001*	0.193 (0.098, 0.288)	<.001*
	Heavy (≥30.0 g alcohol/d)	–	–	0.000 (reference)	–	0.000 (reference)	–
Household income (HI)	<25 percentile	–	–	1.354 (1.214, 1.494)	<.001*	1.292 (1.151, 1.432)	<.001*
	25 ≤ HI <50 percentile	–	–	0.454 (0.376, 0.532)	<.001*	0.419 (0.342, 0.497)	<.001*
	50 ≤ HI <75 percentile	–	–	0.153 (0.088, 0.219)	<.001*	0.139 (0.075, 0.203)	<.001*
	≥75 percentile	–	–	0.000 (reference)	–	0.000 (reference)	–
Body mass index	(kg/m^2)	–	–	–	–	−0.045 (−0.055, −0.036)	<.001*
Self-reported oral health status	Good	–	–	–	–	−0.691 (−0.759, −0.623)	<.001*
	Bad	–	–	–	–	0.000 (reference)	–
R square	–	0.246	–	0.268	–	0.278	–
Adjusted Wald F	–	750.005*	–	411.239*	–	393.986*	–

*Statistically significant ($p < .05$).
Values are presented as estimated β (lower 95% CI, upper 95% CI).
Model 1 Adjusted for age, gender.
Model 2 Adjusted for age, gender, smoking, alcohol, household income.
Model 3 Adjusted for age, gender, smoking, alcohol, household income, body mass index, self-reported oral health status.

number of lost permanent teeth was calculated in subjects with mixed dentition.

Accordingly, the early diagnosis and long-term treatment of asthma appeared to have a strong association with the risk of caries development [17]. The results of this study showed that subjects who were diagnosed with asthma during childhood experienced more tooth loss due to dental caries by 0.407–0.794. In asthmatic patients, the tendency for increased caries occurrence is high due to increased mutans streptococci (MS) levels in the saliva [34]. This is consistent with the results of the previous study stating that the use of inhaled corticosteroids (ICSs) for treating asthma before 3 years of age results in severely demarcated opacities and macroscopic loss of tooth substance, leading to the need for restorative care [17].

This study has some limitations. Asthma is diagnosed according to various criteria; however, in this study, we did not apply a subdivision based on the specific diagnosis category of asthma. Previous studies have shown little difference in the risk of caries development based on the type of medication used for treating asthma. Decrease in saliva secretion and changes in composition have been reported as the main causes of increased risk of caries development. However, this study did not consider the variables associated with the use of other types of asthma medications [15]. Recent studies have suggested that the genetic variation in ameloblastin is associated with caries in asthmatic children, but this was not considered in this study [35].

This study reaffirmed that asthma is one of the major diseases of concern in relation to dental caries. Some asthma medications, such as bronchodilators and anti-inflammatory agents, alter salivary secretion; the latter is reported to be an important factor in increasing caries by increasing MS levels in the saliva, and it requires additional management [16,19,34]. In addition, asthmatic patients commonly experience dry mouth caused by medication and therefore increase their consumption of sweet drinks and sweets between

meals [19]. They also experience gingivitis, often with altered oral biofilm levels, and gum bleeding, which requires preventive care.

In the case of dental caries in early adulthood, the possibility of progression to an edentulous status is expected with increase in age. This was consistent with the results of studies that found that the prevalence of caries and loss of premature teeth are more frequent in childhood [9,26]. Previous studies have shown that asthmatic children have the highest caries levels after 10 years of age, and this is associated with poor oral hygiene and greater MS levels in the saliva [34]. Reportedly, dental caries at an early age results in poor nutritional intake, which leads to an increased risk of obesity, chronic obstructive pulmonary disease, decreased cognitive function and increased mortality due to cardiovascular disease. These results indicate that active management of asthmatic patients is necessary in the field of dentistry [36].

The oral health effects of medicines used for asthma need to be recognised in the fields of medicine and dentistry. In Korea, there is a lack of unified understanding of diseases due to the separate education systems for dentistry and medicine. Asthma is a relatively common disease, and the side effects of long-term medication have been reported. In recent years, increased research on this topic has improved our understanding of the dental risks associated with asthma medications. The frequent consumption of sugary medications, and failure to regularly use fluoridated rinses, have been reported positive correlation to an increased number of early caries lesions [37]. Long-term use or addiction can be an important factor in increasing dental caries, so it is necessary to use sugar-free medication actively [38,39]. Methods, such as the use of spacer devices, changes in ICSs, dosage and frequency, and rinsing and gargling of the oral cavity, have been recommended [14].

In dentistry, clinical practitioners must be aware of the risk factors associated with asthma and use caution during the treatment and management of asthmatic patients [10,40]. However, the level of awareness about asthma among the individual dental practitioners is not equivalent to that about other major diseases, such as diabetes, hypertension and heart disease. Clinicians need to be aware of the fact that asthma is a major disease to be considered in relation to dental caries and tooth loss, and they must practice active preventive management of this condition [10,18,21,40].

This study confirmed the association between the age at asthma diagnosis and the number of permanent teeth lost due to caries. An analysis of the fourth, fifth and sixth KNHANES datasets (2007–2014) showed that tooth loss significantly increased after early diagnosis of asthma at 0–6 years of age ($\beta = 0.560$, $p < .001$) and 7–12 years of age ($\beta = 0.437$, $p < .001$). Clinicians need to shift their perception of dental risks associated with young asthmatic patients. It is necessary to provide active oral health care comprising periodic bone checking and dental caries prevention.

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Disclosure statement

The authors declare that they have no conflict of interests.

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