



Analysis of application of dental sedation in attention deficit hyperactivity disorder (ADHD) patients using the Korean National Health Insurance data

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Background: Attention deficit hyperactivity disorder (ADHD) is characterized by a persistent pattern of inattention and/or hyperactivity-impulsivity that interferes with functioning or development. It has a worldwide pooled prevalence of 5.29%. The characteristics of ADHD can increase the probability of dental treatment, while special behavior management can be required to allow proper treatment. In South Korea, the use of sedation in dental treatment has rapidly increased in recent decades. The present study aimed to investigate the trend and effects of sedation in patients with ADHD undergoing dental treatment in South Korea.

Methods: The study used customized health information data provided by the Korean National Health Insurance Service. Among patients with the record of sedative use during the period from January 2007 to September 2019, those with International Classification of Diseases-10 codes for ADHD (F90, F91) were selected; the data of their overall insurance claims for dental treatment were then analyzed. The patients' age, gender, sedative use, and dental treatment were analyzed per year. The annual number of general anesthesia or sedation cases was also analyzed, and changes in the method of behavior management with increasing age were examined.

Results: The study involved 7,654 patients with ADHD (6,270 males; 1,384 females). The total number of dental treatments was 137,778, while the number of sedation cases was 16,109, among which 13,052 involved male patients and 3,057 female patients. The number of general anesthesia cases was 631, among which 538 involved male patients and 93 female patients. The most frequently used sedation method in the dental treatment of patients with ADHD was N₂O inhalation. The percentage of sedation cases was highest in patients aged 4 years, and it decreased with increasing age.

Conclusion: In South Korea, both sedation and dental treatments were slightly more common in patients with ADHD than in the general population. With increasing age, the frequency of dental treatments and the percentage of sedation cases decreased.

Keywords: Attention Deficit Hyperactivity Disorder; National Health Insurance; Sedation.



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INTRODUCTION

According to the 5th edition of the American Psychiatric Association's Diagnostic and Statistical Manual, attention deficit hyperactivity disorder (ADHD)

is a mental disorder showing a persistent pattern of inattention and/or hyperactivity-impulsivity that interferes with functioning or development. Its symptoms can persist into adulthood [1] and it has a worldwide-pooled prevalence of 5.29% [2], although this varies slightly according to the gender and age of the subjects.

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Data provided by the Korean National Health Insurance Service (NHIS) showed that the annual mean number of patients diagnosed with ADHD during the period from 2007 to 2019 was approximately 50,000, implying that approximately 1 in 1,000 individuals in South Korea had ADHD. As such, the prevalence in South Korea is lower than that reported by Polanczyk et al. [2], perhaps because the statistics from South Korea take into account the total population, rather than children and adolescents only, among whom ADHD occurs mostly frequently.

It is not clear whether dental caries is correlated with ADHD [3]; however, it is known that tooth brushing habit and dietary control are difficult to implement in patients with ADHD [4], who also show a higher incidence of accidental injuries [5]. Oral habits such as bruxism and nail biting are also more frequent in patients with ADHD [6,7], so related dental problems occur more easily. It is these conditions that likely increase the number of dental visits in patients with ADHD.

Nevertheless, visiting the dental clinic or hospital induces fear in all individuals, with or without ADHD. As such, behavior management is particularly important in dentistry [8]. In a study by Blomqvist et al., the level of dental anxiety in patients with ADHD was not higher than in the control group, although the authors reported a greater number of problems related to behavior management in these patients [9]. Atmella et al. also reported that pediatric patients with ADHD were more difficult to manage; instructions regarding hygiene were particularly difficult to communicate [6]. In summary, dental treatment in patients with ADHD poses a whole new dimension of challenges.

In South Korea, the number of dental sedation (SED) cases has increased over the recent past 10 years [10], so the number of cases of dental SED and general anesthesia (GA) is likely to have increased in patients with ADHD as well.

The NHIS in South Korea has been active for more than 30 years. Notably, the NHIS recently signed an agreement to provide limited open access to the databases. This has prompted active research based on

the databases [11]. The goals of the present study, which was based on the data provided by the NHIS, were as follows: (1) ascertain the current practice of dental SED in patients with ADHD in South Korea; (2) examine changes in the percentage of SED or GA according to the age of the patients, the dental diagnosis, and the number of visits to dental clinics or hospitals.

METHODS

1. Study design and population

The study was conducted with the approval from the Institutional Review Board of Seoul National University School of Dentistry (IRB No. S-020200006). Before the study was started, the Healthcare Insurance Review & Assessment Service (HIRA) in South Korea approved the use of the customized health information (M20191014119) of the Healthcare Bigdata Hub (<https://opendata.hira.or.kr/>). As the data source for the subjects in this study, NHIS payment data during the period from January 2007 to September 2019 were used.

First, a request was made to the Healthcare Bigdata Hub for the payment data of patients at dental hospitals and dental clinics who made insurance claims for one of the following eight sedatives: chloral hydrate, hydroxyzine, propofol, sevoflurane, midazolam, triazolam, N₂O, or dexmedetomidine, which can be used in dental SED. To analyze the medical history of each patient, the general summary information (200 table), treatments (300 table), and diagnoses (400 table) were extracted from the data warehouse containing information about medical treatments carried out between January 2007 and September 2019.

The International Classification of Diseases (ICD)-10 codes of the 400 table were searched in the remote statistical analysis system, and patients with the ICD-10 codes for ADHD (F90, F91) were selected. To select patients with pure ADHD, patients with the ICD-10 codes for other, comorbid mental disorders, such as autism, brain injury, cerebral palsy, mental retardation, or

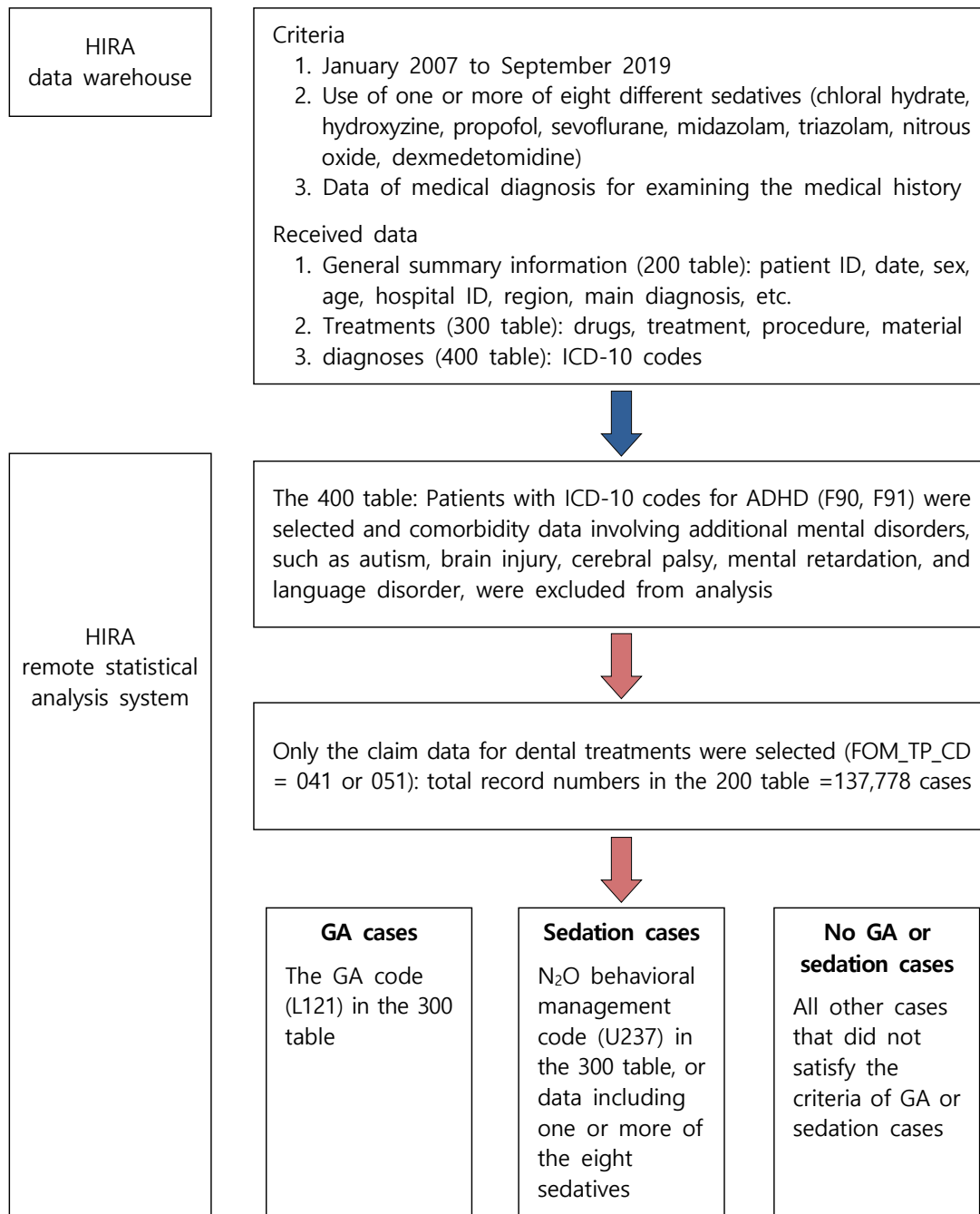


Fig. 1. The process of data extraction from the National Health Insurance Service (NHIS) data. ADHD, attention deficit hyperactivity disorder; GA, general anesthesia; HIRA, Healthcare Insurance Review and Assessment Service; ICD, International Classification of Diseases; ID, identification number; N₂O, Nitrous Oxide.

language disorder, were excluded.

When only dental claims were selected among all insurance claims of patients with ADHD (FOM_TP_CD = 041 or 051), the total number of dental treatments (200 table) was 137,778 (Fig. 1).

2. Grouping of GA or SED

The GA code (L121) and N₂O behavioral management code (U237) were searched in the medical service item (DIV_CD; treatment, medical materials, and drugs) of the treatment table (300 table) for each of the 137,778 cases.

Cases with the GA code were classified as cases of GA. Cases with the N₂O behavioral management code rather than the GA code, or with one or more of the eight sedatives listed above as a named generic drug (GNL_CD) in the treatment table (300 table), were classified as SED cases. All others were classified as No GA or SED cases, where neither GA nor SED had been performed.

3. Yearly trend of patients with ADHD by dental treatment, GA, or SED cases

For analysis, the pseudonym personal identification number (JID), pseudonym hospital identification number (YID), sex, age, and claim date were used as the information found in the general summary information table (the 200 table). All dental treatment cases from January 2007 to September 2019 were categorized into the GA, SED, and No GA or SED groups. Next, the JID was used to calculate the number of patients per group. In addition, the YID was used to calculate the number of dental clinics and hospitals. The sex data were used to estimate gender ratio.

To determine the annual changes, the number of dental treatment cases per year was estimated, as were the numbers of SED or GA cases per year, and a graph was drawn. In addition, a graph of the annual number of patients and the number of dental treatments was drawn, as was a graph of the percentage of SED or GA among all dental treatment cases.

4. Yearly trend of patients with ADHD by age

The age of patients with ADHD receiving dental treatments was analyzed by year. The age data could not be extracted for patients aged ≥ 8 years, and only periodic data were obtained. A diagnosis of ADHD is only possible when a child is over the age of 4 years, while the criteria can only be applied to patients aged at least 7 years [12]. Nonetheless, we had access to accumulated data from the past 13 years, so that a patient whose 2007 data were obtained could be matched with the 2019 data after 13 years. Moreover, the data contained

dental treatments from both before and after the ADHD diagnosis.

Thus, analysis by year would show an increase in the mean age of the analyzed patients with each passing year. In fact, the possibility of analyzing patients aged ≤ 4 years may have been lower in the years approaching 2019. Therefore, the study calculated the differences in age by year based on the age at ADHD diagnosis. On this basis, graphs of the frequency of dental treatments by age were drawn, as were graphs of SED or GA percentages by age.

5. Yearly trend of patients with ADHD by dental diagnosis

The main diagnosis requiring dental treatment was analyzed in the general summary information (200 table). The names of dental diagnoses were categorized into 40 groups based on the ICD-10 codes, and the frequency of each group was analyzed. Diagnosis according to frequency was analyzed, while the number of SED or GA cases upon dental treatment was calculated for each diagnosis type, and the percentage was presented as a table. Diagnosis types with a high percentage of SED or GA were analyzed separately.

6. Annual changes in sedative use and SED method

The annual numbers of cases that used GA, N₂O only, chloral hydrate and hydroxyzine, and midazolam, were analyzed by compiling the data of the GA code, N₂O behavioral management code, and the use of the eight sedatives listed above. The number of dental clinics and hospitals where SED or GA was performed was also analyzed by year.

7. Changes in the percentage of SED with an increased number of dental treatment visits

Next, the percentage of SED was analyzed in patients with ADHD according to the number of visits to dental clinics and hospitals. The frequency of visits was high as the data were from the past 13 years. The probability of significant dental treatment, rather than a simple

Table 1. Total number of dental treatments in patients with ADHD

		Cases	Number of patients	Number of hospital visits
No sedation or GA	Male	97726 (70.93%)	6259 (81.77%)	9032 (88.77%)
	Female	23312 (16.91%)	1383 (18.06%)	3448 (33.89%)
Sedation	Male	13052 (9.47%)	5668 (74.05%)	565 (5.55%)
	Female	3057 (2.21%)	1279 (16.71%)	381 (3.74%)
GA	Male	538 (0.39%)	496 (6.48%)	76 (0.74%)
	Female	93 (0.06%)	84 (1.09%)	39 (0.38%)
Total		137,778	7,654	10,174

ADHD, attention deficit hyperactivity disorder; GA, general anesthesia.

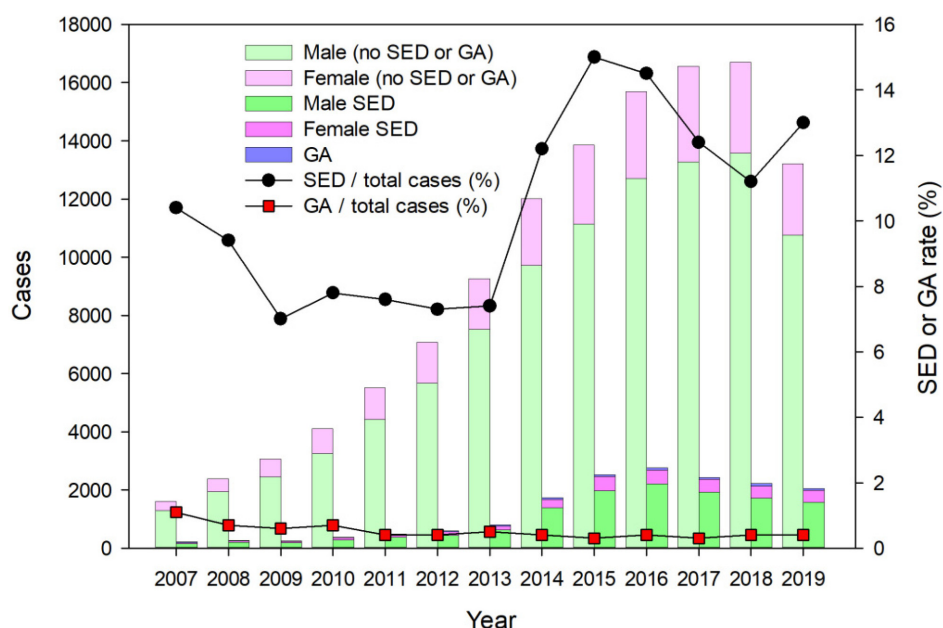


Fig. 2. Number of dental treatments for patients with ADHD in each year shows an increasing trend. The percentage of sedation shows the largest increase (14%) in 2015, followed by a fall. The data source after 2016 shows a fall in the percentage of patients with younger age, coinciding with a fall in the sedation rate. ADHD, attention deficit hyperactivity disorder; GA, general anesthesia; SED, sedation.

follow-up visit, was increased in patients with ≥ 5 visits. The number of first-visit patients was also analyzed, and a graph was drawn to depict differences in the percentage of SED according to the year of visit.

RESULTS

The total number of patients with ADHD among the 137,778 dental treatment cases in the insurance claim records from January 2007 to September 2019, was 7,654 (6,270 males; 1,384 females). The total number of SED cases was 16,109 (11.69%), among which 13,052 involved male patients and 3,057 female patients. Total

631 (0.46%) cases of GA was performed in 538 cases of male patients and 93 cases of female patients. Table 1 presents the number of dental hospitals and clinics where GA or SED was performed.

1. Yearly trend of patients with ADHD by dental treatments, GA or SED cases

The annual number of dental treatment cases in patients with ADHD increased from $\leq 2,000$ in 2007 to $\geq 18,000$ in 2018. The percentage of SED cases showed the largest increase in 2015, at 14% (Fig. 2). The annual number of patients with ADHD who received dental treatments increased from ≤ 600 in 2007 to $\geq 5,000$ in 2018. The percentage of patients in whom SED was performed

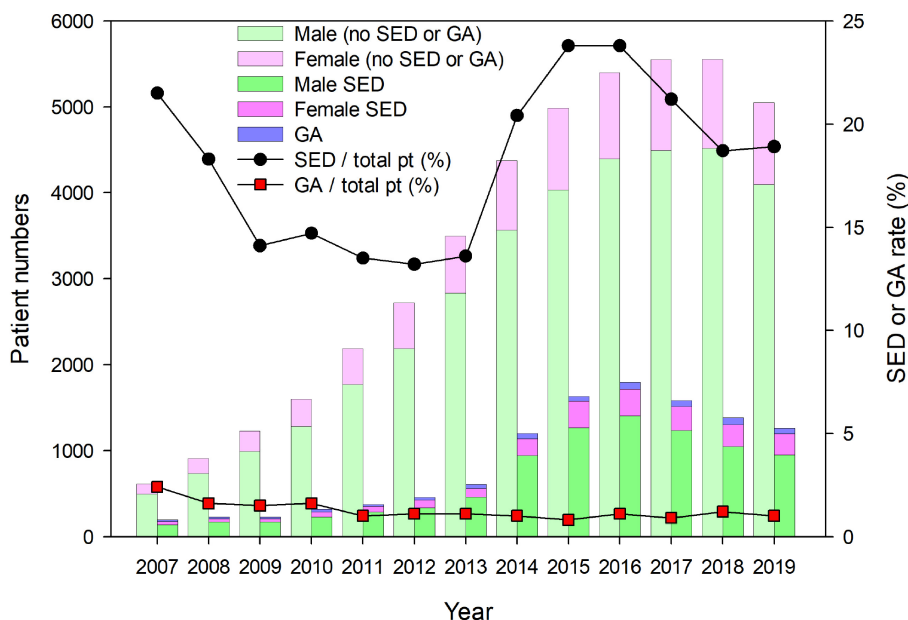


Fig. 3. A graph showing the number of patients with ADHD who received dental treatments in each year. The number of SED cases reached its peak in 2016 and then decreased. The number of GA cases did not show a marked increase. ADHD, attention deficit hyperactivity disorder; GA, general anesthesia; SED, sedation.

Table 2. Yearly trend of the patients with ADHD by age

Age	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	Total
0-2	109	168	217		274	292	231	131	37	13	3			1,698
2	179	217	319	364	417	501	577	530	299	97	29	9		3,538
3	158	258	281	400	498	524	714	864	820	475	133	33	13	5,171
4	101	175	237	306	474	591	679	1,023	1,253	1,135	659	215	65	6,913
5	67	71	72	124	226	357	449	773	1,028	1,184	1,432	1,666	1,340	9,030
6	90	80	118	234	374	478	753	1,116	1,321	1,614	1,830	1,606	866	10,480
7	61	71	72	124	226	357	449	773	1,028	1,184	1,435	1,666	1,340	8,783
8-15	142	179	215	262	308	427	650	1,015	1,499	2,094	2,624	3,442	4,015	16,872
16-30	16	14	22	41	55	74	79	113	140	186	228	267	257	1,495
30-40		1	1	1	3	2	2	4	4	5	4	4	3	34
40-50					1	2			1			1		5

ADHD, attention deficit hyperactivity disorder.

showed the largest increase in 2016, at 24% (Fig. 3). Nevertheless, the percentage of SED cases decreased as the percentage of pediatric patients in the data source also fell after 2016.

2. Yearly trend of patients with ADHD by age

The age distribution of patients with ADHD showed a decreasing trend in those aged ≤ 2 years, but an increasing trend in those aged ≥ 5 years from 2007 to 2019 (Table 2), perhaps because not all subjects were diagnosed with ADHD.

From the total dataset, the data of patients diagnosed

with ADHD who were aged between 2 and 9 years were extracted, and the percentages of SED and GA were calculated. The highest number of SED cases was obtained from patients aged 6 years, while the highest percentage of SED cases was obtained from patients aged 4 years. The number of dental treatment cases decreased with increasing age, but the percentage of SED cases fell to an even greater extent. Conversely, the percentage of GA cases increased with the increase in age, as SED alone could not ensure adequate behavior management in patients with more severe ADHD (Fig. 4). In the years around 2016, the number of patients with ADHD aged

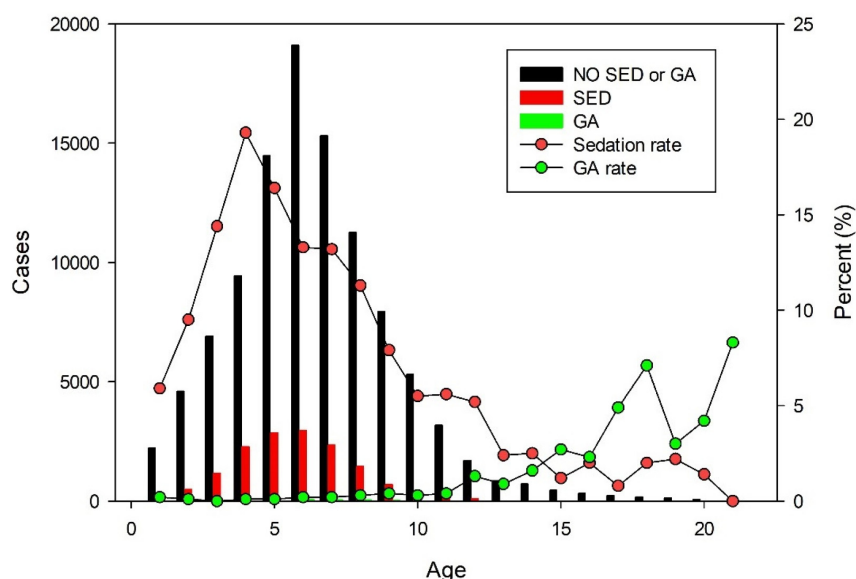


Fig. 4. From the total dataset, only patients aged 2–9 years who were diagnosed with ADHD were selected. Their age was estimated in each year to draw a graph showing the SED and GA cases. The estimated rates showed that the largest number of SED cases occurred in patients aged 6 years, while the highest percentage of SED cases occurred in patients aged 4 years. ADHD, attention deficit hyperactivity disorder; GA, general anesthesia; SED, sedation.

Table 3. Ranking of diagnosis by frequency and type of dental anesthesia used

Ranking	Diagnosis	Total cases	Percentage (%)	Cumulative percentage (%)	Number of No SED or GA	Number of SED	Number of GA	Rate of SED or GA (%)	SED rate (%)	GA rate (%)
1	Dental caries	43274	31.4	31.4	38100	5160	14	88	11.9	0
2	Disorders of tooth development and eruption	37179	26.9	58.3	35699	1338	142	96	3.5	0.3
3	Pulpitis	26422	19.1	77.4	18326	8059	37	69.3	30.5	0.1
4	Gingivitis	9397	6.8	84.2	9308	85	4	99	0.9	0
5	Prophylactic measures	6652	4.8	89	5780	871	1	86.8	13	0
6	Abrasion of teeth	2335	1.6	90.6	2280	54	1	97.6	2.3	0
7	Impaction tooth	2250	1.6	92.2	1938	155	157	86.1	6.8	6.9
8	Fracture of tooth	1857	1.3	93.5	1681	73	103	90.5	3.9	5.5
9	Stomatitis	1791	1.2	94.7	1770	19	2	98.8	1	0.1
10	Anomalies of tooth position, displacement	1308	0.9	95.6	1291	13	4	98.7	0.9	0.3
11	Avulsion of tooth	1213	0.8	96.4	1179	33	1	97.1	2.7	0
12	Open wound of tongue or floor of mouth	582	0.4	96.8	469	107	6	80.5	18.3	1
13	Other cysts of oral region	483	0.3	97.1	425	10	48	87.9	2	9.9
14	Fitting and adjustment of dental prosthesis	454	0.3	97.4	436	18		96	3.9	
15	Exfoliation of teeth	410	0.2	97.6	384	26		93.6	6.3	
16	Gingival recession or enlargement	352	0.2	97.8	348	4		98.8	1.1	
17	Benign neoplasm of craniofacial bones	284	0.2	98	225	3	56	79.2	1	19.7
18	Superficial injury of lip and oral cavity	243	0.1	98.1	239	4		98.3	1.6	
19	Fracture or loss of dental prosthesis	240	0.1	98.2	225	15		93.7	6.2	
20	Tongue tie	212	0.1	98.3	166	37	9	78.3	17.4	4.2

GA, general anesthesia; SED, sedation.

Table 4. Ranking of diagnosis by sedation rate

Ranking	Diagnosis	Total cases	Number of No SED or GA	Number of SED	Number of GA	Rate of no SED or GA	SED rate (%)	GA rate (%)
1	Pulpitis	26422	18326	8059	37	69.3	30.5	0.1
2	Open wound of tongue or floor of mouth	582	469	107	6	80.5	18.3	1
3	Tongue tie	212	166	37	9	78.3	17.4	4.2
4	Prophylactic measures	6652	5780	871	1	86.8	13	0
5	Dental caries	43274	38100	5160	14	88	11.9	0
6	Other diseases of salivary glands	33	28	3	2	84.8	9	6
7	Impaction tooth	2250	1938	155	157	86.1	6.8	6.9
8	Exfoliation of teeth	410	384	26		93.6	6.3	0
9	Fracture or loss of dental prosthesis	240	225	15		93.7	6.2	0
10	Other and unspecified lesions of oral mucosa	48	45	3		93.7	6.2	0
11	Cleft lip and palate	52	43	3	6	82.6	5.7	11.5
12	Benign neoplasm of oropharynx	43	40	2	1	93	4.6	2.3
13	Fracture of tooth	1857	1681	73	103	90.5	3.9	5.5
14	Fitting and adjustment of dental prosthesis	454	436	18		96	3.9	0
15	Disorders of tooth development and eruption	37179	35699	1338	142	96	3.5	0.3

GA, general anesthesia; SED, sedation.

Table 5. Ranking of diagnosis by GA rate

Ranking	Diagnosis	Total cases	Number of No SED or GA	Number of SED	Number of GA	Rate of no SED or GA	SED rate (%)	GA rate (%)
1	Benign neoplasm of craniofacial bones	284	225	3	56	79.2	1	19.7
2	Cleft palate	52	45	0	7	86.5	0	13.4
3	Cleft lip and palate	52	43	3	6	82.6	5.7	11.5
4	Other cysts of oral region	483	425	10	48	87.9	2	9.9
5	Impaction tooth	2250	1938	155	157	86.1	6.8	6.9
6	Other diseases of salivary glands	33	28	3	2	84.8	9	6
7	Fracture of tooth	1857	1681	73	103	90.5	3.9	5.5
8	Cleft lip	19	18	0	1	94.7	0	5.2
9	Tongue tie	212	166	37	9	78.3	17.4	4.2
10	Benign neoplasm of oropharynx	43	40	2	1	93	4.6	2.3
11	Open wound of tongue or floor of mouth	582	469	107	6	80.5	18.3	1
12	Disorders of tooth development and eruption	37179	35699	1338	142	96	3.5	0.3
13	Anomalies of tooth position, displacement	1308	1291	13	4	98.7	0.9	0.3
14	Pulpitis	26422	18326	8059	37	69.3	30.5	0.1
15	Stomatitis	1791	1770	19	2	98.8	1	0.1

GA, general anesthesia; SED, sedation.

16–30 years showed an approximately twofold increase (Table 2). Over 99% of dental SEDs were performed in patients ≤ 15 years old, and 27.41% of all GA cases was performed in patients aged 16–30 years, while the percentage of patients aged ≥ 16 years among all patients with ADHD visiting a dental hospital or clinic was only 2.4%.

3. Yearly trend of patients with ADHD by dental diagnosis

The most frequent diagnosis in patients with ADHD visiting a dental hospital or clinic was dental caries, followed by disorders of tooth development, eruption, and pulpitis (Table 3). Rearrangement of these rankings according to the percentage of SED cases showed that pulpitis had the highest percentage, followed by open wound of the tongue

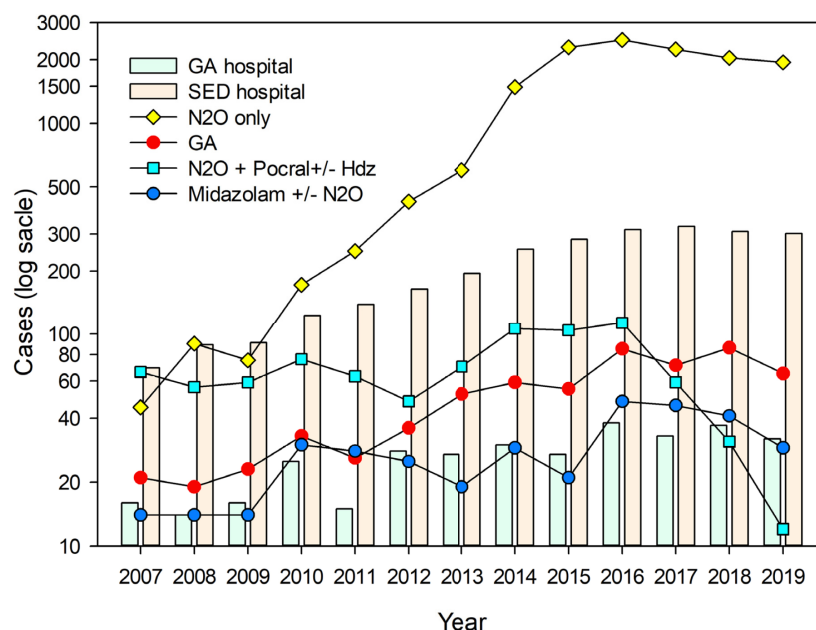


Fig. 5. A graph showing the changes in the number of sedatives used in GA and SED cases each year. The annual number of dental hospitals or clinics where SED or GA was performed was also analyzed. The most notable changes was the increase in the use of N₂O inhalation sedation. The use of chloral hydrate + hydroxyzine + N₂O sedation did not show a notable pattern of increase until 2016, when it was exceeded by the use of midazolam. GA, general anesthesia; Hdz, Hydroxyzine; N₂O, Nitrous Oxide; Pocral, Chloral hydrate; SED, sedation.

or floor of mouth, and tongue tie (Table 4). Ranking according to the percentage of GA cases showed that benign neoplasm of craniofacial bones was at the top rank, followed by cleft palate and cleft lip and palate, indicating that GA was frequently performed in patients requiring oral and maxillofacial surgery (Table 5).

4. Annual changes in sedative use and SED method

The most frequently used SED method in dental treatments of patients with ADHD was N₂O inhalation (84.51%), followed by GA (3.77%) and chloral hydrate + hydroxyzine + N₂O (2.47%). Excluding N₂O-only SED and GA—the two most frequently used SED methods in dental treatments of patients with ADHD—the yearly trend of sedative use showed a decrease in the use of chloral hydrate and an increase in the use of midazolam (Fig. 5).

5. Changes in the percentage of SED with an increased number of dental treatment visits

The percentage of SED cases showed a decrease in patients with more visits to a dental clinic or hospital

(Fig. 6), probably because these patients had adapted to the dental treatments, or because their behavior had improved with age. Conversely, the percentage of SED increased in the years approaching 2019.

DISCUSSION

Among the 7,654 patients with ADHD, the number of male patients (6,270) was more than 4.5-fold higher than that of female patients (1,384). This result cannot be attributed to gender differences of dental disease prevalence, as the study did not target a specific dental disease. Instead, the result was likely due to differing ADHD symptoms in females, which also contribute to delayed detection and diagnosis [12,13].

In South Korea, the range of insurance benefits covering ADHD treatments was extended to patients aged between 19 and 66 years in September 2016. This may be why the number of patients with ADHD who received dental treatments showed a nearly twofold increase in patients aged ≥ 16 years around 2016 (Table 2).

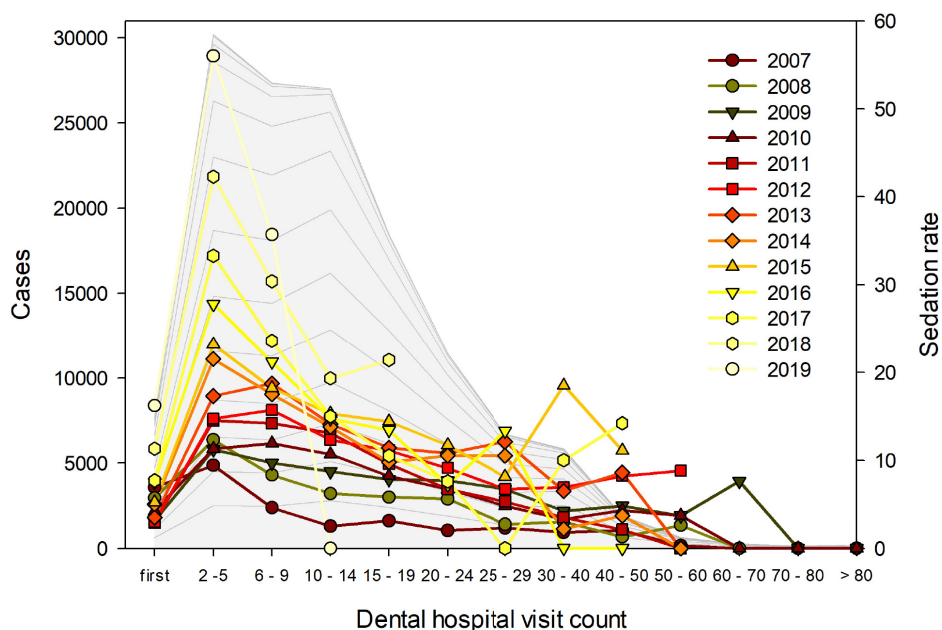


Fig. 6. With increased number of visits to dental hospitals or clinics, the rate of sedation showed a decrease, perhaps because the patient adapted to the dental treatments or improved with age. The rate of sedation increased in the years approaching 2019.

However, ADHD was still mostly distributed among pediatric and adolescent patients, while over 99% of SED cases were performed in patients aged ≤ 15 years, with a notable high percentage of GA in patients aged ≥ 16 years.

The first drugs of choice in ADHD treatment include the psychostimulant drugs amphetamine and methylphenidate [14]. The use of methylphenidate to treat ADHD facilitated awakening from GA induced by isoflurane and propofol in a study using rats [15,16], while the use of psychostimulant drugs combined with opioids increased the analgesic effect but decreased the effect of opioid-induced sedation [17]. However, in another study, the use of sedatives showed no significant difference between patients with ADHD and a control group. Using midazolam and fentanyl for procedural sedation in the emergency department, there were no significant difference in sedation depth or sedative dose between patients with ADHD and the control group, but the length of stay in the recovery room was longer in patients with ADHD [18]. In line with this, when using propofol in MRI imaging, no increase in sedative dose was required to achieve the same sedation depth in

patients with ADHD as in the control group [19].

In a survey conducted on pediatric dentists in Texas, USA in 2007, the most frequently used methods of pharmacological behavior management to control the behavior of patients with ADHD were N_2O -only sedation, followed by diazepam + N_2O sedation, and meperidine + promethazine + N_2O sedation [20]. In the present study, based on NHIS data from South Korea, the total number of sedatives used from 2007 to 2019 showed that the most frequently used sedation method was N_2O -only sedation, followed by GA, chloral hydrate + hydroxyzine + N_2O sedation, and chloral hydrate + N_2O sedation. In the US, the production of chloral hydrate was terminated in 2012 [21], after which the use of chloral hydrate has continuously decreased [22]. In South Korea, likewise, the Korean Dental Society of Anesthesiology (KDSA) has led education efforts to convince dentists that midazolam is safer than chloral hydrate, since moderate sedation is sufficient for the sedation depth required in dental clinic outpatient settings [23,24]. The percentage use of midazolam has thus shown a steady increase, whereas the use of chloral hydrate has gradually decreased (Fig. 5). In addition, dentists in South Korea are unfamiliar with

meperidine and promethazine, as both drugs are insufficiently introduced during anesthesiology courses in South Korea [25]. This likely caused the difference in the type of sedative used among different countries, and the choice is likely not influenced by whether the patient has ADHD.

In a study conducted in 2007 to compare trazodone and midazolam in the oral sedation of pediatric patients with ADHD who were undergoing computed tomography (CT), trazodone was more effective than midazolam [26]. However, no further study has yet been conducted. In addition, midazolam sedation may be unsuitable in patients with ADHD, as suggested by Marshall in 1999, who reported that a patient showed severe aggression after midazolam administration [27]. However, this paradoxical reaction to midazolam is related to dose and individual variability in the drug response [28]. The suitability of midazolam sedation in patients with ADHD is yet to be verified.

In dentistry in South Korea, sedation is mainly applied to pediatric patients. Although the demand for sedation in adult patients has recently increased [25], dental sedation in adults is not yet covered by the NHIS. As a result, the number of sedation cases among adult patients in the present study was likely underestimated.

According to Yang et al., who conducted a study on pediatric dentists in South Korea, the mean age of the targets of sedation was 3–4 years, while no respondents used N₂O-only sedation [29]. In the present study, the number and percentage of sedation cases were analyzed in patients diagnosed with ADHD between the ages of 2 and 9 years, and the largest number of sedation cases occurred in patients aged 6 years, while the percentage of sedation cases was highest in patients aged 4 years (Fig. 4). This difference between the study by Yang et al. and the present study likely arose because the former involved a questionnaire that depended on the memory of the respondents; as is the case with questionnaires, the multiple-choice questions may have limited the patients' age group. In contrast, the present study used the actual number of cases based on insurance claims. In addition,

while the present study found that N₂O-only sedation was the most frequently used sedative regimen, excluding GA, the study by Yang et al. reported that none of the respondents used N₂O-only sedation [29]. This was the most puzzling difference, although it may be relevant that Yang et al. targeted pediatric dentists only. As pediatric dentists are trained to control deep sedation as well, it is likely that they combined other sedatives alongside N₂O inhalation sedation. Moreover, the number of respondents in the Yang et al. study was 111 [29], while the present study analyzed more than 130,000 claims from patients with ADHD. Notably, Bae et al. conducted a survey on 181 respondents, including general dentists [25], and found that 23.7% used N₂O-only sedation. This means that the percentage of N₂O-only sedation seemed to increase with an increasing percentage of general dentists. The data provided by the Korean NHIS in the present study targeted no specific group of specialists, but rather the number of insurance claims made by all dentists in South Korea, which may be why the results of the present study differed from those of the Yang et al. study.

The present study had a few limitations. Firstly, the age that discriminates adult from pediatric patients was not clear in the data. Secondly, no data were available from cases of dental anesthesia without insurance claims. Finally, the subjects in the present study were patients with ADHD. However, the study did not analyze all patients who received dental treatment in South Korea, preventing any comparison with overall trend. Nevertheless, the present study was significant because it used extensive national data focused on dental anesthesia in patients with ADHD. Few previous studies have considered this question. Based on the findings of the present and follow-up studies, a more specific and nationwide vision should be suggested for the NHIS.

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