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.

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.
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 particular 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
Dental sedation in ADHD using KNHI data

Criteria
1. January 2007 to September 2019
2. Use of one or more of eight different sedatives (chloral hydrate, hydroxyzine, propofol, sevoflurane, midazolam, triazolam, nitrous oxide, dexmedetomidine)
3. Data of medical diagnosis for examining the medical history

Received data
1. General summary information (200 table): patient ID, date, sex, age, hospital ID, region, main diagnosis, etc.
2. Treatments (300 table): drugs, treatment, procedure, material
3. Diagnoses (400 table): ICD-10 codes

The 400 table: Patients with ICD-10 codes for ADHD (F90, F91) were selected and comorbidity data involving additional mental disorders, such as autism, brain injury, cerebral palsy, mental retardation, and language disorder, were excluded from analysis.

Only the claim data for dental treatments were selected (FOM_TP_CD = 041 or 051): total record numbers in the 200 table = 137,778 cases.

GA cases
The GA code (L121) in the 300 table

Sedation cases
N2O behavioral management code (U237) in the 300 table, or data including one or more of the eight sedatives

No GA or sedation cases
All other cases that did not satisfy the criteria of GA or sedation cases

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.

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).
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 ≤ 2,000 in 2007 to ≥ 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 ≥ 5,000 in 2018. The percentage of patients in whom SED was performed.
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 (%) | Rate of SED (%) | Rate of GA (%) | GA rate (%) |
|---------|------------------------------------------|-------------|----------------|---------------------------|------------------------|---------------|---------------|----------------------|----------------|---------------|-------------|
| 1       | Dental caries                             | 43274       | 31.4           | 31.4                      | 38100                  | 14            | 88            | 11.9                 | 3.5            | 0.3           |             |
| 2       | Disorders of tooth development and eruption | 37179       | 26.9           | 58.3                      | 35699                  | 142           | 96            | 30.5                 | 0.1            |              |             |
| 3       | Pulpitis                                 | 26422       | 19.1           | 77.4                      | 18326                  | 37            | 69.3          | 11.9                 | 0.3            | 0             |             |
| 4       | Gingivitis                               | 9397        | 6.8            | 84.2                      | 9308                   | 85            | 4             | 9.6                  | 0.9            | 0             |             |
| 5       | Prophylactic measures                    | 6652        | 4.8            | 89.1                      | 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            | 93.6                 | 6.3            | 6.3           |             |
| 15      | Exfoliation of teeth                     | 410         | 0.2            | 97.6                      | 384                    | 26            | 96            | 98.8                 | 1.1            | 1.1           |             |
| 16      | Gingival recession or enlargement        | 352         | 0.2            | 97.8                      | 348                    | 4             | 98.8          | 98.3                 | 1.6            | 0.3           |             |
| 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          | 93.7                 | 6.2            | 6.2           |             |
| 19      | Fracture or loss of dental prosthesis    | 240         | 0.1            | 98.2                      | 225                    | 15            | 93.7          | 98.3                 | 17.4           | 4.2           |             |

GA, general anesthesia; SED, sedation.
Table 4. Ranking of diagnosis by sedation rate

| Ranking | Diagnosis                                | Total cases | Number of 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            | 9            | 93.6                  | 6.3          | 0           |
| 9       | Fracture or loss of dental prosthesis    | 240         | 225                | 15            | 9            | 93.7                  | 6.2          | 0           |
| 10      | Other and unspecified lesions of oral mucosa | 48       | 45                 | 3             | 1            | 93                    | 4.6          | 2.3         |
| 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           | 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.

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).
However, ADHD was still mostly distributed among pediatric and adolescent patients, while over 99% of SED cases were performed in patients aged $\leq 15$ years, with a notable high percentage of GA in patients aged $\geq 16$ 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 N₂O-only sedation, followed by diazepam + N₂O sedation, and meperidine + promethazine + N₂O 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 N₂O-only sedation, followed by GA, chloral hydrate + hydroxyzine + N₂O sedation, and chloral hydrate + N₂O 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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