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ORIGINAL RESEARCH

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Use of nitrous oxide sedation by pediatric dentists: a cross-sectional study of the Jordanian experience

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Abstract

Background: Children's fear and anxiety may lead to behavioral management problems which could prevent the provision of successful dental treatment.Nitrous Oxide (N_2O) sedation facilitates the provision of dental treatment by reducing anxiety. Aims: To survey the Jordanian pediatric dentists and determine the current status of N_2O sedation use by pediatric dentists, and factors related to N_2O equipment and safety. **Methods**: A cross-sectional survey was conducted among registered pediatric dentists who are practicing in Jordan. The sample comprised 77 participants. A fifteen-item questionnaire included information on demographic, N_2O equipment, utilization, and safety was used. Descriptive and analytical statistical analysis were performed. The Chi-square test of independence was used to test relationships between subgroups. Statistical significance was set at 0.05. **Results**: Of all pediatric dentists who participated in this survey, 37.7% use N_2O sedation in their clinical practice. Almost all pediatric dentists who provide N_2O sedation are practicing in the private sector. Of respondents who provide N_2O sedation, 44.8% obtain written consent forms from parents before sedation, 93.1% don't have N_2O ambient level monitoring system, 37.9% don't have any monitoring equipment, 13.8% don't have emergency certification, and 41.4% had never updated their medical emergency certification. **Conclusions**: While N_2O sedation is used by a notable portion of pediatric dentists in the surveyed population, significant gaps exist in consent procedures, adherence to safety protocols, and emergency preparedness. These findings highlight a need for enhanced training, stricter regulations, and better enforcement to ensure patient safety and quality of care during N_2O sedation.

Keywords

Nitrous oxide; Pediatric dentistry; Sedation; Behavior management; Jordan

1. Introduction

Behavior guidance constitutes a continuous interactive process *involving* the dental team, patient and parent [1]. It aims to facilitate communication and education before and during care provision. The goal of behavior guidance is to establish or maintain communication as well as to stop unwanted or unsafe behaviors [2]. A conceptual model developed to investigate the relationship between individual/parental behaviors and dental caries/visit patterns revealed a negative association between dental anxiety and both Frankl Behavior Scale scores and children's dental visit behaviors [3]. Methods of managing anxiety and guiding child behavior are required to meet this need. Despite non-pharmacological behavioral management techniques, many children are still unable to tolerate dental treatment. Sedation might be considered in such cases as a way to reduce anxiety and facilitate dental treatment provision [4]. Nitrous oxide (N_2O) is one of the most used agents for sedation [4]. N_2O exerts a threefold effect: anesthetic, analgesic and anxiolytic. Its anesthetic action stems from the noncompetitive inhibition of N-methyl-D-aspartate receptor antagonists in the central nervous system. The analgesic effect is attributed to the release of endogenous opioids that bind to opioid receptors, producing pain relief comparable to morphine. Finally, the anti-anxiety effect is attained through GABA-A receptor activation [5].

Since the introduction of N_2O into dentistry, the drug has become increasingly popular for dental anxiety management [6]. Due to its very low plasma solubility, N_2O has a rapid onset of action and rapid elimination which is independent of treatment time (two to three minutes) when N_2O is discontinued [7].

N_2O has sedative, analgesic and hypnotic properties [8]. It induces muscular relaxation and is anticonvulsant. Children who have undergone traumatizing dental procedures can benefit from anterograde amnesia [9, 10].

N_2O inhalation sedation is recognized as a safe and effective technique to reduce anxiety, produce analgesia, and enhance effective communication between patients and health care providers [11]. It is evident that N_2O inhalation sedation has a high overall success rate of over 90%, making it an

effective way to provide dental treatment to pre-cooperative and/or anxious children and adolescents and increasing their trust in the dentist [12, 13]. With N_2O sedation and behavior management techniques, dental general anesthesia was reduced in young patients with high dental treatment needs and poor cooperation with dental treatments [14]. The need to diagnose and treat, as well as the safety of the patient and practitioner, should be considered before using N_2O sedation [11]. An individualized approach to weighing N_2O risks and benefits would be optimal in a particular case [15]. A recent article suggested a predictive model comprising age, baseline Frankl behavior score, anticipatory guidance, dental procedures, and whether the child enjoys rhythmic activities could be used to assess whether a child could complete dental treatment with behavior success under N_2O, improving case selection [16].

The Jordan Medical Council (JMC) is the governing body responsible for licensing and overseeing training programs for dental specialties. To sit for the Jordanian Board exam, candidates must meet the JMC's specific requirements. A variety of institutions and programs offer pediatric dentistry training for the Jordanian Board. This is done either as a three-year clinical master's program by dental schools or a three-year residency program offered by the Ministry of Health and Royal Jordanian Medical Services [17]. To achieve proficiency in pediatric dentistry, trainees must gain experience in managing and monitoring pediatric dental patients including conscious sedation with nitrous oxide. As Jordan lacks national pediatric dentistry guidelines, the JMC follows the guidelines established by the American Academy of Pediatric Dentistry (AAPD) [18].

Data regarding nitrous oxide sedation practices among Jordanian pediatric dentists are currently lacking. The rationale of this study centers on establishing a comprehensive understanding of nitrous oxide (N_2O) sedation practices within Jordanian pediatric dentistry. This includes determining the status of N_2O sedation use, adherence to established guidelines for safe and effective administration, and investigating factors influencing N_2O sedation utilization. Ultimately, the study aims to identify areas for improvement, policy development, and clinical practice to enhance the quality and safety of pediatric dental care *involving* sedation in Jordan. This study will add valuable insights to the global understanding of N_2O use in pediatric dentistry. The hypothesis of the study is that a significant proportion of Jordanian pediatric dentists utilize nitrous oxide sedation in their practice and their adherence to established guidelines for nitrous oxide sedation is optimal (including medical safety, emergency response training, monitoring, and equipment maintenance).

2. Material and methods

Jordan Dental Association was contacted to obtain access to the names and addresses of pediatric dentists in Jordan. The study took place from the beginning of February 2020 until the end of June 2020.

2.1 Study design

A descriptive cross-sectional study was conducted among pediatric dentists in Jordan. The list of pediatric dentists licensed and registered with the Jordan Dental Association (JDA) and actively practicing in Jordan was officially provided by the JDA.

2.2 Study setting and participants

To ensure the representativeness of the sample, the census sampling technique was used to recruit participants. All pediatric dentists were invited to participate in the study. In the most recent JDA database, 90 pediatric dentists were listed as active in Jordan. At 0.05 two-tailed level of significance and 0.05 margin of error, at least 63 pediatric dentists were required [19]. 70% of the sample (63 pediatric dentists) would meet the minimum required response rate and enhance the representativeness of the target population by reaching the recommended 70–80% response rate [20]. The final study sample comprised 77 pediatric dentists. Only licensed, registered, and active pediatric dentists practicing in Jordan were included. The study excluded general dentists, specialists other than pediatric dentists, dentists practicing pediatric dentistry in Jordan but not licensed as specialists, and pediatric dentists not practicing in Jordan.

2.3 The questionnaire

Built on structured questionnaires used in earlier related studies [21–25], a questionnaire was designed according to the specific objectives of the study. Using simple and clear language, 50 questions were written in a short and specific manner. Demographic information, N_2O equipment and utilization, procedural information, and safety were all included in the questionnaire.

Targeted pediatric dentists were contacted by phone to seek approval for enrollment in the study. Pediatric dentists were thoroughly informed about the study's aims and potential benefits. One investigator (YN) distributed questionnaires directly to pediatric dentists at their place of practice. Pediatric dentists who use N_2O sedation in their clinical practice were asked to answer all the questions included in the questionnaire. Pediatric dentists who do not use N_2O sedation in their practice were asked only to answer the first eleven questions (demographic data and reasons not to use N_2O). A week after distribution, the investigator collected the questionnaires to verify that all questions had been answered correctly.

2.4 Pilot study

A pilot study was conducted with five pediatric dentists to assess readability and interpreting questions, as well as average completion time. The questionnaire took respondents about 15 minutes to complete and was modified based on suggestions and comments. Reliability was tested by asking 10% of the participants to complete the questionnaire on two separate occasions, two weeks apart. The test-retest reliability result was 0.85.

2.5 Data analysis

Data analysis was performed using the Statistical Package for Social Sciences (SPSS) software version 11.0 (SPSS®: Inc., Chicago, IL, USA). Frequencies and percentages were calculated. In addition, the Chi-square test of independence was used to test relationships between subgroups. $p < 0.05$ indicated statistically significant differences.

3. Results

The study excluded five pediatric dentists who took part in the pilot study. The questionnaire was sent to the remaining 85 pediatric dentists. Of the 85 pediatric dentists targeted, 77 pediatric dentists (90.6%) completed the questionnaire. More than one-half of respondents (54.5%) followed a residency program at a hospital and the others (45.5%) followed a university program, and approximately one-half (49.3%) practiced in the private sector. The majority (76.6%) of participants practice in the central region of Jordan. Most participants (80.5%) are certified in Basic Life Support (BLS), and nearly one-third had never updated their medical emergencies certificate. The demographic characteristics of the participants are shown in Table 1.

In this study, 37.7% of pediatric dentists used N_2O sedation in their clinical practice. Lack of availability in clinics/hospitals (66.7%), high cost (31.3%), and lack of potency (20.8%) were the principal reasons for not using N_2O sedation. The leading reason for N_2O sedation use was to calm the patient and reduce anxiety (100%), followed by to help with gag reflexes (58.6%), and to increase patients' tolerance for longer appointments (55.2%).

Most respondents indicated the use of portable N_2O delivery systems (93.1%). During N_2O sedation, gases were removed using scavenging systems (69.0%). Many respondents (93.1%) do not employ an ambient N_2O monitoring system. Others (50.0%) stated that their N_2O delivery system had been repaired or altered due to rubber bag or mask deterioration. None of the respondents experienced any N_2O equipment problems that jeopardized the patient's safety. Table 2 summarized N_2O equipment data.

Table 3 shows information related to N_2O sedation utilization. N_2O inhalation sedation was mostly used with local anesthetic injections (86.2%), for pulp and root canal therapy (82.8%), and dental extraction (65.5%). There were no gender differences reported by most respondents (86.2%) regarding the need for N_2O sedation. Moreover, the age range (6–12) years was the most likely age group treated using N_2O sedation. Duration of N_2O sedation appointments of 40–60 minutes was the most reported range (51.7%), followed by 20–30 minutes (48.3%). 75.9% of participants indicated that they usually treat one quadrant at an appointment. The standard titration technique is most commonly used for N_2O titration. The most frequently used range of N_2O concentration was >30–50%. N_2O sedation depth was mostly mild (62.1%). N_2O sedation success rates have ranged from >50 to 75%. Of all respondents who used N_2O sedation, less than one half of participants (44.8%) reported that they obtained a written consent form from parents before N_2O sedation.

3.1 Safety of nitrous oxide sedation

Table 4 shows responses about monitoring during sedation and side effects and concerns related to N_2O. 58.6% of respondents who administer N_2O sedation reported having a pulse oximeter, 31.0% a blood pressure cuff, and 10.3% a stethoscope in their clinics. Despite this, more than a third (37.9%) of respondents reported not having a monitoring device. More than one half (55.2%) of respondents claimed that they typically use a pulse oximeter for monitoring during N_2O sedation. A few (6.9%) reported using a blood pressure cuff. However, all respondents reported using clinical signs (color, respiratory rate, and level of consciousness) during N_2O sedation. Above half of the respondents (51.7%) indicated that their patients never close their eyes for periods exceeding 5 minutes when under N_2O sedation.

Table 4 also shows side effects and concerns related to N_2O. The majority reported that their pediatric patients "never had" side effects during N_2O sedation sessions (nausea, vomiting and excessive sweating). Also, parents expressed concern about N_2O's effects on children. Safety was the primary concern of parents (73.9%), followed by potential brain effects (30.4%) and depth of sedation (26.1%). A minority (17.2%) of parents indicated the occurrence of side effects on their children after N_2O sedation sessions. The most important reported side effects were "nausea and vomiting" (80.0%) followed by "nasal bleeding" (20.0%). The minority of respondents (13.8%) reported that their staff and office personnel inquired or complained about N_2O ambient effects. The reported concerns were related to neurological effect and reproduction effects.

Only 24.1% of participants recorded physiological parameters time-based. 52.9% reported recording every 10 minutes, 28.6% every 5 minutes, and 28.6% reported recording at the beginning and end of treatment. 57.1% of cases were recorded by the "dental assistant". Most of the time (75.9%), "doctor and assistant" were the only ones present in the operatory during N_2O sedation.

3.2 Nitrous oxide sedation: demographics, related factors and side effects

A Pearson Chi-Square statistical test was used to determine the relationship between N_2O sedation provision and the variables. Other variables, including emergency certification and updating medical emergency certificate did not differ significantly in N_2O sedation use ($p > 0.05$). Only place of practice ($p < 0.001$) appeared to affect N_2O sedation use (Table 5).

Pediatric dentist's emergency certification, updating medical emergencies certificate, using of scavenging system and the average duration of N_2O sedation appointment had not a significant effect on the occurrence of side effects during N_2O sedation ($p > 0.05$). Only the N_2O concentration frequently used led to side effects during N_2O sedation ($p = 0.05$) (Table 6).

4. Discussion

This descriptive cross-sectional study is the first conducted in Jordan among active pediatric dentists registered at JDA to

TABLE 1. Socio-demographic characteristics of the study sample (N = 77).

Characteristics	N (%)
Gender	
Male	17 (22.1)
Female	60 (77.9)
Pediatric dentistry specialty program	
University	35 (45.5)
Hospital (Residency)	42 (54.5)
Number of years of clinical practice in general	
0–5 yr	15 (19.5)
6–10 yr	15 (19.5)
11–15 yr	23 (29.9)
16–20 yr	13 (16.9)
>20 yr	11 (14.3)
Jordanian board exam passing	
Yes	63 (81.8)
Not required at that time	14 (18.2)
Place of practice	
Universities	11 (14.3)
MOH	17 (22.1)
RMS	11 (14.3)
Private sector	38 (49.3)
Geographic region of practice	
North	15 (19.5)
Central	59 (76.6)
South	3 (3.9)
Number of patients seen weekly	
1–25	28 (36.4)
26–50	36 (46.8)
51–100	11 (14.3)
>100	2 (2.6)
Emergency certification	
BLS	62 (80.5)
PALS	25 (32.5)
ACLS	8 (10.4)
None	14 (18.2)
Updating medical emergencies certificate	
Once a year	6 (7.8)
Twice yearly	4 (5.2)
Every 2 years	33 (42.9)
3–4 years	4 (5.2)
Never	30 (39.0)

MOH: Ministry of Health; RMS: Royal Medical Services; BLS: Basic Life Support; PALS: Pediatric Advanced Life Support; ACLS: Advanced Cardiac Life Support.

TABLE 2. Information on N_2O equipment used by participants (N = 29).

Characteristics	N (%)
Type of N_2O delivery system	
Portable	27 (93.1)
Central/fixed	2 (6.9)
Methods used to remove gas during N_2O sedation	
Scavenging system	20 (69.0)
Increased air turnover	11 (37.9)
Fans and exhaust	4 (13.8)
Work in larger operatories	1 (3.4)
None	3 (10.3)
Having N_2O ambient level monitoring system	
Yes	2 (6.9)
No	27 (93.1)
Methods used to monitor ambient N_2O level	
Chemical sensitive badges	1 (50.0)
Infrared testing	1 (50.0)
Ambient level of N_2O	
Equal or less than 50 ppm	2 (100.0)
More than 50 ppm	0 (0.0)
Alteration or repair to N_2O delivery system	
Yes	10 (34.5)
No	19 (65.5)
Reasons for alteration or repair	
Rubber bag or mask deterioration	5 (50.0)
New equipment installation	3 (30.0)
Failure of the fail-safe system	1 (10.0)
Malfunctions of flow meters	1 (10.0)
Equipment problems imperiling patients	
Yes	0 (0.0)
No	29 (100.0)

N_2O: nitrous oxide.

explore to explore the use of N_2O sedation in dental practice. The hypothesis of the study is not proved. While a notable proportion of pediatric dentists use N_2O sedation, their adherence to established guidelines is suboptimal in several key areas, including consent procedures, monitoring and emergency preparedness.

The study sample is representative since almost all active licensed and registered pediatric dentists at JDA participated. A pilot questionnaire was administered in person to pediatric dentists at their places of practice. This led to a higher response rate and a completion rate of the questionnaires. This survey achieved an excellent response rate of 90.6%, higher than what is generally reported in surveys of healthcare professionals [26, 27]. The high response rate may be a reflection of the concern pediatric dentists in Jordan have regarding N_2O sedation studies.

In the current study, 37.7% of pediatric dentists in Jordan provide N_2O sedation in their clinical practice. In the absence of similar previous studies, a direct comparison of the results cannot be made. Despite this, Wilson [21] and Wilson and Gosnell [22] found that the majority of American Academy of Pediatric Dentistry members (89% and 97%) used N_2O in their practices. Results may differ due to differences in legislation in different countries as well as the distribution of pediatric dentists in the private and public sectors. Additionally, female pediatric dentists provide N_2O at a higher rate than male pediatric dentists. Probably because most JDA pediatric dentists are female. Almost all N_2O respondents are from the private sector. This is possibly because pediatric dentists at universities, Royal Medical Services (RMS), and the Ministry of Health (MOH) have mentioned the lack of N_2O facilities and monitoring equipment.

N_2O are primarily provided by pediatric dentists in Jordan's central geographical region. Based on the JDA list, pediatric

TABLE 3. N_2O sedation utilization (N = 29).

Characteristics	N (%)
Patients' gender most likely to be treated under N_2O sedation	
Male	1 (3.4)
Female	3 (10.3)
No gender differences	25 (86.2)
Patients' age group likely to be treated using N_2O sedation	
3–5 yr	4 (13.8)
6–12 yr	20 (69.0)
No specific age group	5 (17.2)
Treatments and interventions provided under N_2O sedation	
With local anesthetic injections	25 (86.2)
Pulp and root canal therapy	24 (82.8)
Dental extraction	19 (65.5)
Permanent teeth treatments	11 (37.9)
Fillings and crowns	7 (24.1)
Impressions	7 (24.1)
The average duration of the N_2O sedation appointment/min	
20–30	14 (48.3)
40–60	15 (51.7)
Number of treated teeth at each N_2O sedation appointment	
Quadrant	22 (75.9)
More than one tooth	5 (17.2)
Half mouth	1 (3.4)
Full mouth	1 (3.4)
Frequency of N_2O sedation session	
1–2/weekly	14 (48.3)
3–5/weekly	2 (6.9)
More than 5/weekly	6 (20.7)
1–2/monthly	6 (20.7)
2–3/monthly	1 (3.4)
The average percentage of pediatric patients require N_2O sedation/week	
1–20%	19 (65.5)
21–40%	6 (20.7)
41–60%	2 (6.9)
61–80%	2 (6.9)
Methods of N_2O titration	
Standard titration technique only	25 (86.2)
Rapid induction technique only	0 (0.0)
Both	4 (13.8)
Concentrations of N_2O frequently used	
11–30%	6 (20.7)
31–50%	18 (62.1)
More than 50%	2 (6.9)
Combinations (10–50%)	3 (10.3)
Depth of sedation	
Mild	18 (62.1)
Moderate	11 (37.9)
Estimated N_2O sedation success rate	
Less than 25%	2 (6.9)
26–50%	9 (31.0)
51–75%	11 (37.9)
More than 76%	7 (24.1)

N_2O: nitrous oxide.

TABLE 4. Information on monitoring during the use of N_2O sedation and data regarding side effects and concerns related to N_2O (N = 29).

Monitoring	N (%)
Monitors in office	
Pulse oximeter	17 (58.6)
Blood pressure cuff	9 (31.0)
Stethoscope	3 (10.3)
Capnograph	0 (0.0)
None	11 (37.9)
Monitors used with N_2O sedation	
Clinical observation and monitoring (Color, respiratory rate, level of consciousness)	29 (100.0)
Pulse oximeter	16 (55.2)
Blood pressure cuff	2 (6.9)
Stethoscope	0 (0.0)
Capnograph	0 (0.0)
None	0 (0.0)
Eyes closed for periods exceeding 5 minutes with N_2O sedation	
Never close their eyes	15 (51.7)
Infrequently	13 (44.8)
Frequently	1 (3.4)
Always	0 (0.0)
Patients' negative side effects during the N_2O sedation	
Never	17 (58.6)
Infrequently	12 (41.4)
Parent concern regarding the effect of N_2O on their children	
Yes	22 (75.9)
No	7 (24.1)
Type of concern expressed	
Safety	17 (73.9)
Depth of sedation	6 (26.1)
The duration that N_2O remains in the body	3 (13.0)
Potential brain effects	7 (30.4)
Side effects and concerns	N (%)
Side effects indicated by parents after N_2O sedation	
Yes	5 (17.2)
No	24 (82.8)
Frequency of side effects indicated after N_2O sedation	
Rarely	3 (60.0)
Infrequently	2 (40.0)
Frequently	0 (0.0)
Always	0 (0.0)
Side effects mostly indicated	
Nausea and vomiting	4 (80.0)
Nasal bleeding	1 (20.0)
Experienced compromised airways during the use of N_2O sedation	
Yes	0 (0.0)
No	29 (100.0)
Experienced the need for EMS resulting from N_2O sedation	
Yes	0 (0.0)
No	29 (100.0)
Staff concerns about N_2O ambient effect	
Yes	4 (13.8)
No	25 (86.2)
Type of concern expressed	
Reproduction	3 (75.0)
Neurologic	2 (50.0)

N_2O: nitrous oxide; EMS: Emergency Medical Services.

TABLE 5. N_2O sedation use by demographic characteristics.

Characteristics	N_2O use		*p*-value
	Yes N (%)	No N (%)	
Gender			
Male	6 (35.3)	11 (64.7)	0.819
Female	23 (38.3)	37 (61.7)	
Pediatric dentistry specialty program			
University	15 (42.9)	20 (57.1)	0.390
Hospital Residency	14 (33.3)	28 (66.7)	
Number of years of clinical practice in general			
0–5 yr	5 (33.3)	10 (66.7)	
6–10 yr	6 (40.0)	9 (60.0)	
11–15 yr	9 (39.1)	14 (60.9)	0.948
16–20 yr	4 (30.8)	9 (69.2)	
>20 yr	5 (45.5)	6 (54.5)	
Jordanian board exam passing			
Yes	23 (36.5)	40 (63.5)	0.657
Not required at that time	6 (42.9)	8 (57.1)	
Place of practice			
Universities	1 (9.1)	10 (90.9)	
MOH	0 (0.0)	17 (100.0)	<0.001
RMS	0 (0.0)	11 (100.0)	
Private sector	28 (73.7)	10 (26.3)	
Geographic region of practice			
North	2 (13.3)	13 (86.7)	
Center	26 (44.1)	33 (55.9)	0.089
South	1 (33.3)	2 (66.7)	
Number of patients seen weekly			
1–25	12 (42.9)	16 (57.1)	
26–50	10 (27.8)	26 (72.2)	0.350
51–100	6 (54.5)	5 (45.5)	
>100	1 (50.0)	1 (50.0)	
Emergency certification			
BLS			
Yes	24 (38.7)	38 (61.3)	0.700
No	5 (33.3)	10 (66.7)	
PALS			
Yes	9 (36.0)	16 (64.0)	0.835
No	20 (38.5)	32 (61.5)	
ACLS			
Yes	5 (62.5)	3 (37.3)	0.145
No	24 (34.8)	45 (65.2)	
None			
Yes	4 (28.6)	10 (71.4)	0.549
No	25 (39.7)	38 (60.3)	
Updating medical emergencies certificate			
Once a year	3 (50.0)	3 (50.0)	
Twice yearly	1 (25.0)	3 (75.0)	
Every 2 years	11 (33.3)	22 (66.7)	0.869
3–4 years	2 (50.0)	2 (50.0)	
Never	12 (40.0)	18 (60.0)	

N_2O: nitrous oxide; MOH: Ministry of Health; RMS: Royal Medical Services; BLS: Basic Life Support; PALS: Pediatric Advanced Life Support; ACLS: Advanced Cardiac Life Support.

TABLE 6. Factors that could result in patient's side effects during and after N_2O sedation (N = 29).

	Patient's negative side effects during N_2O sedation			Patient's negative side effects after N_2O sedation		
	No N (%)	Yes N (%)	*p*-value	No N (%)	Yes N (%)	*p*-value
Emergency Certification (BLS, PALS, ACLS)						
Yes	3 (75.0)	1 (25.0)	0.622	0 (0.0)	4 (100.0)	1.000
None	14 (56.0)	11 (44.0)		5 (20.0)	20 (80.0)	
Updating medical emergencies certificate						
Once a year	2 (66.7)	1 (33.3)	0.796	0 (0.0)	3 (100.0)	0.731
Twice yearly	0 (0.0)	1 (0.0)		0 (0.0)	1 (100.0)	
Every 2 years	7 (63.6)	4 (36.4)		3 (27.3)	8 (72.7)	
3–4 years	7 (58.3)	5 (41.7)		2 (16.7)	10 (83.3)	
Never	1 (50.0)	1 (50.0)		0 (0.0)	2 (100.0)	
Methods used to remove gas during N_2O sedation						
Scavenging system						
Yes	10 (50.0)	10 (50.0)	0.234	5 (25.0)	15 (75.0)	0.153
No	7 (77.8)	2 (22.2)		0 (0.0)	9 (100.0)	
The average duration of the N_2O sedation appointment/minutes						
20–30	9 (64.3)	5 (35.7)	0.550	3 (21.4)	11 (78.6)	0.651
40–60	8 (53.3)	7 (46.7)		2 (13.3)	13 (86.7)	
Concentrations of N_2O frequently used						
11–30%	6 (100.0)	0 (0.0)	0.050	0 (0.0)	6 (100.0)	0.297
31–50%	9 (50.0)	9 (50.0)		5 (27.8)	13 (72.2)	
More than 50%	0 (0.0)	2 (100.0)		0 (0.0)	2 (100.0)	
Combinations (10–50%)	2 (66.7)	1 (33.3)		0 (0.0)	3 (100.0)	

N_2O: nitrous oxide; BLS: Basic Life Support; PALS: Pediatric Advanced Life Support; ACLS: Advanced Cardiac Life Support.

dentists are mostly located in the capital and central regions of the country.

Similar to Wilson and Gosnell's [22] study, respondents in this study depend primarily on scavenging systems to remove wasted or exhaled gases during N_2O sessions, either as the sole method or used in combination with other methods. However, the majority do not employ an ambient N_2O monitoring system. Bioenvironmental risks of N_2O include long-term exposure risks to personnel due to bone marrow suppression and reproductive dysfunction, as well as greenhouse effects [11, 28]. In this study, and also in Wilson and Gosnell's [22] study, a minority of respondents reported that their staff and office personnel inquired or complained about the ambient effects of N_2O, but they mostly reported neurological effects and reproduction concerns. During dental surgery, the ambient N_2O level should be <50 ppm. This ambient N_2O level should be controlled through regular system maintenance, scavenging system use, good operating room ventilation, and other ways to keep it at a low level [29]. By employing an ambient N_2O monitoring system, dental practices can significantly reduce the risks associated with nitrous oxide exposure, safeguarding both patient and staff well-being.

One-third of respondents in the present study claimed that their N_2O delivery system had been altered, repaired or modified, while a lower percentage was reported by Wilson and Wilson and Gosnell [21, 22]. Results differ due to the large variation in the proportion of pediatric dentists using N_2O between studies, as well as the type of N_2O delivery system used (central versus portable). A rubber bag or mask deterioration accounted for half of the repairs reported in the present study. A pediatric dentist reported a fail-safe system failure and another reported flow meter malfunctions. All N_2O system components, including the reservoir bag, should therefore be routinely inspected for cracks, wear, and tears to prevent such problems. If detected, repairs should be made immediately [11, 30]. Flow meters should be checked regularly, and an in-line oxygen analyzer must be used. The fail-safe system needs to be checked and calibrated regularly [11, 30]. As reported by Wilson and Wilson and Gosnell [21, 22], in the present study no pediatric dentist reported any N_2O equipment problems that jeopardized patient safety. Utilizing advanced monitoring equipment can enhance patient safety during nitrous oxide administration. To ensure accuracy, this equipment must be regularly maintained and calibrated. The most reported dental procedures and treatments provided under N_2O sedation in the present study were local anesthetic injections, pulp and root canal therapy, and tooth extraction. Other studies have found similar results. Among pediatric dentists in the UK [23] the

most common dental procedures *involving* conscious sedation were simple extractions, dental trauma, surgical extractions and pulpotomy. A survey among French dental practitioners [24] showed that N_2O sedation was used mainly for restorative/endodontic works and surgery.

Most respondents in the present study reported that there was no sex difference concerning N_2O provision. Most patients were treated with N_2O sedation between the ages of 6–12 years. A comparable result was reported in a study conducted among French general practitioners [24] where N_2O was provided to all ages with a slight predominance of children between 6 and 10 years old. During this age, the child may require more comprehensive dental treatment, such as extractions and pulp therapy (the mixed dentition stage). Also, at this stage, the child could have had negative previous dental experience where the need for N_2O increases to reduce their anxiety and increase their tolerance for more and longer appointments.

In this study, it was found that N_2O sedation appointments typically last between 20–30 minutes or 40–60 minutes. Most respondents usually treat one quadrant at a time. These different average time durations could be attributed to the various treatments provided and the different number of teeth treated in each session. A comparable result was reported in a study conducted among French general practitioners [24], which showed that 37 minutes was the average duration of N_2O sedation sessions.

A lower frequency of N_2O sedation sessions and a lower percentage of patient requiring N_2O sedation sessions per week were found in this study [21, 22]. The questionnaire used in this study did not investigate the cost of N_2O sedation sessions and thus cannot discuss the financial aspect. However, the difficulty in convincing patients' parents and the financial aspect might hinder the provision of N_2O in Jordan.

The standard titration technique is the most common method used for titration as reported by the majority in the present study. Also, the majority reported using 31–50% N_2O concentrations. This is consistent with the concentration required to achieve ideal sedation [11]. A review of records of patients undergoing N_2O sedation conducted by Malamed and Clark [31] demonstrated that the typical patient requires 30 to 40% N_2O to achieve ideal sedation. Also, these results are in accordance with Wilson [21] and Wilson and Gosnell [22] studies where most participants reported N_2O titration throughout the procedure and the majority used 31–50% N_2O.

Unexpectedly and unfortunately, less than half of the participants in this study reported that they obtained written informed consent from parents before N_2O sedation. This finding contradicts the AAPD recommendation that informed consent must be obtained from the parent before N_2O/O_2 administration [11]. In Jordan, the medical and health accountability law went into effect in 2018, requiring all medical interventions and procedures to be approved by the patient [32]. However, the law does not obligate the practitioner to obtain a written consent before sedation [32]. Informed consent should be obtained before any dental procedure performed under any type of sedation by pediatric dentists. Patients and parents of minors can participate in the informed consent process and retain autonomy over the care they receive. Informed consent could limit practitioner liability for miscommunication claims [33]. A recent systematic review which provided an overview of the available guidelines on the use of N_2O in pediatric dentistry reported that while informed consent is required from the parent/guardian and must be documented in the patient's record before administering N_2O, there is a difference in obtaining consent between guidelines. Several guidelines recommend written informed consent, while others recommend informed consent only [34]. Recommending or mandating written informed consent for sedation procedures aligns with global standards and demonstrates professionalism. Written informed consent must be obtained prior to N_2O sedation, according to medical and health accountability law. This will ensure that both ethical and legal obligations are met, prioritizing the well-being of the child while protecting rights of the parents and the practitioner. Although more than half of the participants reported having a pulse oximeter in their clinics, not all use it during N_2O sedation. Unfortunately, more than one-third of respondents reported no monitors in their clinics. Wilson [21] and Wilson and Gosnell [22] also reported that the majority of AAPD members surveyed did not use any monitors during N_2O alone sedation. Strict regulatory oversight and enforcement of safety standards can deter complacency and ensure compliance. Regular inspections of dental clinics can help identify and address potential safety hazards. When N_2O of $\leq$50% is administered alone with balanced oxygen to a healthy patient (American Society of Anesthesiologists classification I or II), minimal sedation is expected during which minimal monitoring is usually required, and the patients will not need more than observation and periodic assessment of their sedation level. Even with minimal sedation, some children may become moderately sedated as sedation is a continuous process and the practitioner cannot always predict the response of each patient [35, 36]. Certification in emergency response and N_2O administration must be a requirement for licensure and practice.

The majority reported that their pediatric patients never encountered side effects during and after N_2O sedation. The results of the current study show that an increase in N_2O concentration leads to significant side effects to the patient during N_2O sedation. N_2O is well known for causing nausea and vomiting, with an increased incidence associated with longer administration, high N_2O concentrations, poor titration and a heavy meal prior to N_2O administration [37–41]. Epistaxis following inhalational sedation with nitrous oxide/oxygen in the dental setting is a very rare complication but has been previously reported in the literature [42]. Proper instructions and dietary precautions should be given before sedation along with proper administration and monitoring of N_2O to decrease the incidence of these side effects occurrence.

As in previous studies, the majority reported that parents expressed concerns about N_2O effects on their children, mainly about its safety and depth of sedation. Wilson and Gosnell [22] found that half of parents voice concerns about N_2O. Practitioners should be encouraged to increase their knowledge about N_2O and spend time with parents to discuss its characteristics, effects, benefits, shortcomings, and other safety-related issues as parents grow more concerned about their children's safety [22].

Continuing dental education was made legal in Jordan in

2017. This obligates all registered dentists to participate in a cardiopulmonary resuscitation (CPR) course every 5 years to renew his/her professional practicing license. Despite this, a percentage of participants in this study are not certified in emergency certification. Nearly one-third of participants had never updated their medical emergencies certificate. A significant percentage of those who provided N_2O did not have any emergency certification, and less than half had never updated their emergency certification. Periodic emergency courses and lectures should be offered to dentists by all dental health organizations and sectors to enable them to manage any potential complications to ensure patient safety. For pharmacological guidance of behavior in children, N_2O provides excellent safety and efficacy when administered by trained personnel on carefully selected patients [11]. Implementing mandatory training programs for all dental professionals, including continuing education, can ensure their readiness to handle emergency. Certification in emergency response and N_2O administration must be a requirement for licensure and practice.

N_2O sedation physiological parameters are not recorded time-based by most participants in this study. Similar results were found by Wilson and Gosnell [22] in their study where the majority did not use such a time-based record for N_2O alone. A time-based record of physiological parameters is essential for sedation guidelines. However, when N_2O is used alone, guidelines do not promote the use of a time-based record during N_2O sedation but confirm that the patient's record should include the indication of N_2O use, N_2O dosage, duration of the procedure, and post-treatment oxygenation procedure [11, 22].

Considering the present study, the JDA, in collaboration with the MOH and other concerned establishments, is called to enforce new strict regulations that regulate N_2O provision in dental care. Obtaining an informed consent form before N_2O use, and ensuring proper usage, monitoring, installation, and storage, as well as implementing mandatory conscious sedation certification. Also, clinical courses and lectures about N_2O sedation provision are required for pediatric dentists, with emphasis in monitoring, safety, bioenvironmental risks, and long-term exposure risks to personnel. Public awareness campaigns are also necessary to raise public awareness about the importance of medical safety in dental settings. This can empower patients to ask questions and seek out qualified providers. Additionally, educational campaigns can emphasize the risks related to inadequate emergency preparedness.

Questionnaire-based surveys have limitations in that respondents may overreport their answers and there is no assurance that their answers reflect their actual practice situation. Also recall bias may have occurred in relation to services delivered at past dental visits due to some of the factors asked about—for example side effects of patients. Validated questionnaires and representative samples may mitigate these limitations. Previous studies with which the results of the present study can be compared are scarce. Since there are only two studies on N_2O sedation, comparison might not be appropriate since these studies differ greatly in demographic data and situation. The privileges to use N_2O might not be available to most pediatric dentists practicing in health care organizations and hospitals. This fact might cloud the picture of N_2O use in Jordan.

5. Conclusions

Based on this study, more than one-third of Jordan's pediatric dentists use N_2O. The place of practice would significantly affect pediatric dentists' provision and use of N_2O sedation. Concerningly, among N_2O providers, less than half obtain their parents' written consent forms before N_2O sedation. Significant deficiencies exist in safety protocols: the vast majority lack ambient N_2O monitoring, a substantial proportion lack basic monitoring equipment, and a concerning number have either lapsed emergency certifications or lack them entirely.

AVAILABILITY OF DATA AND MATERIALS

The data that support the findings of this study are available from the corresponding author (RLD) upon reasonable request.

AUTHOR CONTRIBUTIONS

LDR—conceived the study and supervised the work. YJA—collected data. LDR and YJA—analysed the data, wrote and revised the manuscript. Both authors have read and approved the final manuscript.

ETHICS APPROVAL AND CONSENT TO PARTICIPATE

The research project was approved by the department of Pediatric Dentistry, the Graduate Studies Committee at the School of Dentistry, and the Council of the School of Graduate Studies at the University of Jordan before the commencement of the study. IRB reference 75/2019/2282 date 27 November 2019. Written informed consents were signed by all pediatric dentists who participated in this study.

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CONFLICT OF INTEREST

The authors declare no conflict of interest.

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