Impact of operators' experience and patients' age on the success of nitrous oxide sedation for dental treatment in children

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Abstract

Aim To evaluate the success rates and potential influencing factors of nitrous oxide sedation for dental treatment in a specialised paediatric dental service.

Materials and methods Medical records of all children treated under nitrous oxide sedation in a specialised pedodontics clinic between 2012 and 2017 were analysed retrospectively for parameters such as age of the patient, experience and change of operating dentists, treatment procedure and success or failure regarding the sedation and treatment.

Results 480 pre-cooperative/anxious patients aged 3 to 17 years (mean 6.7±2.7; 54.6% male) were treated in 803 nitrous oxide sessions. Most children were 6–12-year-olds (n= 271, 56.5%). The overall success rate was 92.7% for all nitrous oxide sessions (95% CI adjusted for multiple sessions: 91-94%). In relation to patients' age, the success rate increased significantly (P=0.041). Over the years of use a clear learning effect can be depicted.

Conclusion Given the high overall success rate of over 90%, nitrous oxide sedation can be a highly effective treatment option for performing dental treatment in pre-cooperative and/or anxious children and adolescents. With age of the children and experience of the dentist, success rates increased.

KEYWORDS Children; Dentistry; Nitrous oxide; Sedation; Treatment.

Introduction

Dental anxiety related to dental procedures and hypersensitivity to pain has been recognised to be an obstacle to the successful treatment in both adults and children. With a prevalence of 10–30% [CED, 2014; Klingberg and Broberg, 2007], dental anxiety is considered to be one of the biggest challenges in the field of paediatric dentistry. This fear of dental treatment may lead to non-cooperative behaviour especially in small children [D'Alessandro et al., 2016; AAPD, 2020; Navit et al., 2015]. This could be also associated with high levels of caries experience in children [Julihn et al., 2006] as untreated dental caries can be a result of a dental fear or behaviour management problems [Murthy et al., 2014].

In Germany, dental general anaesthesia is often used until the age of 12 years, as it is covered by the National Health System to perform dental treatment in uncooperative children. In many other countries like the USA, UK, Italy and France, nitrous oxide sedation is already considered an alternative to dental general anesthesia with high levels of patient satisfaction [Arcari and Ferro, 2008; Daher et al., 2012], especially for short invasive dental procedures such as injection of local anaesthesia, minor surgical procedures such as extraction, frenectomy, treatment of molar incisor hypomineralisation (MIH) or difficult single tooth treatment [Hennequin et al., 2012]. Minimal sedation with nitrous oxide is considered a safe technique [Berge, 1999; Collado et al., 2007] and can be used in healthy patients or in patients with mild systematic disease (ASA I, ASA II) from about 4 years of age [Hallonsten et al., 2003]. Nitrous oxide has a good sedative and moderate analgesic effect, which usually requires an additional local anaesthetic for dental treatment. Some studies [Foley, 2005; Galeotti et al., 2016], showed that treatment under nitrous oxide sedation is not only an effective option in paediatric dentistry, but also highly accepted by parents [Al Zoubi et al., 2019].

In 2013 a statement of the German Dental Society of Anesthesiologists and the working group from DGAI, BDA, DGKiZ and DGZMK concerning the use of nitrous oxide sedation for minimal sedation in paediatric dentistry was published [Philippi-Höhne et al., 2013]. Nonetheless, to our knowledge, there is few international data and none for Germany describing the success rate of nitrous oxide sedation for treatments in paediatric dentistry until now, about 5 years after publication of this statement. Therefore, the aim of this study is to examine the real-life clinical success rate of nitrous oxide sedation for dental treatments in pre-cooperative and fearful paediatric patients, who were treated in the Department of Preventive and Pediatric Dentistry at the University of Greifswald (Germany) between the years 2012 and 2017.

Materials and methods

Study design and ethical approval

This retrospective study analysed the digital medical records of all children treated under nitrous oxide sedation between January 2012 and December 2017 at the Department of Preventive and Pediatric Dentistry at the University of

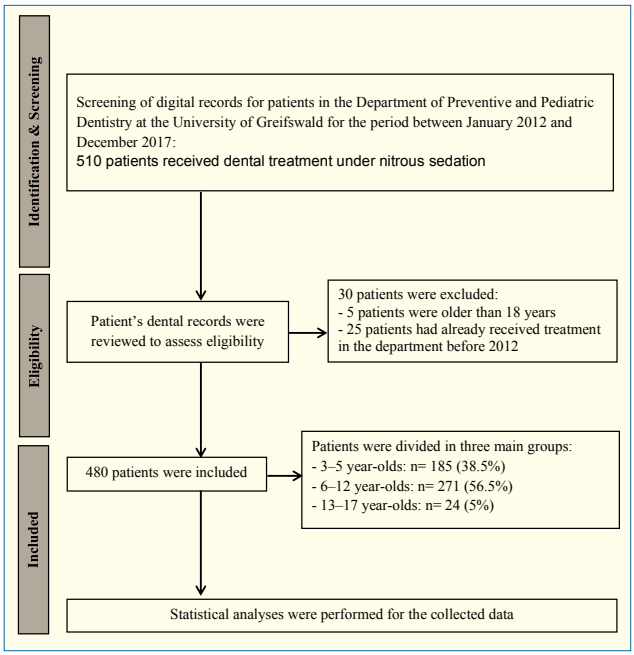

FIG. 1 Flow-chart of the 6 years retrospective study assessing the dental treatment profile in children and success of nitrous oxide sedation in the Department of Preventive and Pediatric Dentistry at the University of Greifswald (Germany).

Greifswald (Fig. 1). Ethical approval was obtained from the Research Ethics Committee of the University of Greifswald (protocol number: BB 028/16, date: 15.03.2016).

Inclusion criteria

• Healthy patients (ASA I and ASA II) treated under nitrous oxide sedation in the time period between January 2012 and December 2017.

• Patients aged between 3 and 17 years at the first nitrous oxide session.

Definition of a failure in a nitrous oxide session

Based on the information provided in the medical dental records, a treatment session with nitrous oxide was considered as a failure in the following cases:

- when the planned dental treatment could not be performed,
- when the patient refused to continue the treatment during the nitrous oxide sedation, or
- when a sedation was planned by the dentist (the patient was assessed to be ready for nitrous oxide sedation and informed about it) but the patient did not accept the nitrous oxide mask in that visit, which meant that the sedation could not be performed or needed to be stopped after few minutes.

Clinical standard procedure for nitrous oxide sedation

For a high-quality medical care while treating the patients under nitrous oxide sedation at the Department of Preventive and Pediatric Dentistry at the University of Greifswald, a clear and detailed checklist, following the international recommended standards (AAPD, EAPD), was designed and followed for every treatment with nitrous oxide since its implementation in 2012.

All sedation sessions were performed using MDM Quantiflex Flowmeter combined with "Complete tube set with double mask – child" (GRODENTA, Oisterwijk, NL). The use of this device allows a titratable nitrous oxide administration. The maximum used concentration of nitrous oxide was 50%. In all sedation sessions patients were monitored using finger clip pulse oximeter.

Statistical analysis

We included age, gender, session sequence, and year of use to predict the failure. The impact of different dental operators in the appointment before the sedation and in the sedation session was also investigated. As this event was sparse [Harrell, 2015], we applied conventional and Bayesian approaches [Wakefield, 2013]. To address the most important mathematical assumption in regression analysis [Gelman and Hill, 2006; Harrell, 2015; James G, 2013], we used restricted cubic splines for continuous variables (5 knots for age, 3 knots for session sequence and year of use). To address the second most important mathematical assumption, we adjusted for the patient level by modeling cluster robust variances in the conventional approach. In the Bayesian approach, the patient level was modelled by random effects with an exponential distribution. We used R software [R Foundation for Statistical Computing, 2020], especially the packages rms [Harrell, 2015], rmsb [Harrell FE, 2021], Stan [Gelman et al., 2021], and loo [Vehtari et al., 2017]. For the Bayesian prediction model, we used the default options of the blrm command [Harrell FE, 2021] except for the distribution (exponential instead of half-normal; with mean of 0.8 for the distribution), number of iterations, and the adapt_delta parameter [Vehtari et al., 2017]. Descriptive statistics were also performed.

Results

In total, 510 patients were treated under nitrous oxide sedation in the period between January 2012 and December 2017 at the Department of Preventive and Pediatric Dentistry at the University of Greifswald/Germany. Of them, 480 patients aged 3 to 17 met the inclusion criteria of the study. They received dental treatment in a total number of 803 nitrous oxide sessions.

Baseline characteristics on patient level								
Age group	3–5 year-olds		6–12 year-olds		13–17 year-olds		Total	
N (%)	185 (38.5)		271 (56.5)		24 (5)		480 (100)	
Mean age (years)	4.5 (±0.6)		7.6 (±1.7)		14.5 (±1.2)		6.7 (±2.7)	
Gender	m	f	m	f	m	f	m	f
N (%)	108 (58.4)	77 (41.6)	143 (52.8)	128 (47.2)	11 (45.8)	13 (54.2)	262 (54.6)	218 (45.4)
dmft at the first session (SD)	5.8 (±3.2)		4.6 (±3.4)		-		5.1 (±3.3)	
DMFT at the first session (SD)	-		0.7 (±1.6)		6.9 (±4.5)		1.2 (±3.2)	

TABLE 1 Baseline characteristics on patient level of children treated under nitrous oxide sedation from 2012 to 2017 at the Department of Preventive and Pediatric Dentistry at the University of Greifswald (Germany).

Characteristics of the study sample

The distribution of the 480 patients (mean age 6.7±2.7 years) according to the age group is shown in Table 1. Almost all the patients treated under nitrous oxide sedation were totally healthy (ASA I), only 6.7% (n=32) had a mild controlled systematic condition (ASA II; e.g. asthma, diabetes, etc.); 45.4% of the patients were female.

The caries experience (mean dmft/DMFT) of the study sample revealed very high values for the pre-school children in the primary dentition (dmft = 5.8±3.2) and for teenagers in the permanent dentition (DMFT = 6.9±4.5) (Table 1).

Nitrous oxide sedation and factors influencing the success rate

At the department of Preventive and Pediatric Dentistry in Greifswald 803 nitrous oxide sedation sessions were performed. The overall success rate was 92.7% (n=744 sessions) for all nitrous oxide sessions (95% CI adjusted for multiple sessions: 91-94%).

The number of nitrous oxide sessions increased with the years of use, where 49 sessions were performed in 2012 (success rate= 83.7%) and 253 sessions were performed in 2017 (success rate= 94.1%). An increase in the success rate during the years of use was also noticed (Table 2).

The most common reason for failure was the lack of cooperation (79.7%, n= 47/59 failure sessions). In 18.6% of these failure sessions, the failure was due to the low or non-acceptance of the nitrous oxide mask. Some of the patients did not accept it before or in the middle of the treatment although the patient was considered ready and informed about the procedure before. In 45.8% of these failure cases (27/59), the failure occurred directly after the administration of the local anaesthetic, where the patient showed a very negative reaction with low cooperation, which is not adequate for continuing the sedation; 72.9% of those failures were considered as total failures and 27.1% as partial failure as a dental treatment was performed without sedation.

Treatment spectrum in nitrous oxide sessions

Treatments were registered for the successful nitrous oxide sedation sessions (744 sessions). In total 1093 dental procedures under sedation, with a mean of 1.5 dental procedures per session were performed. Of those treatments, 77.7% (n= 849) were performed on primary teeth, 22.0% (n= 241) in permanent teeth and 0.3% (n= 3) were related to soft tissue. The most frequently treated teeth in the primary dentition were the first (48.1%; n= 410) and second (39.2%; n= 334) primary molars, and for the permanent dentition the first permanent molars (62.2%; n= 150). A total of 1156 dental treatments under sedation were planned; 94.6% of those treatments were performed successfully under nitrous oxide sedation; 62.7% of the dental treatments under nitrous oxide were minor oral surgeries (i.e. tooth extraction); 9.3% were fillings without the use of local anaesthetic and 7.4% were fillings with anaesthetic (Table 3).

Factors influencing the success rate of nitrous oxide sedation

The discrimination ability of the conventional prediction model was good (c index = 0.74). This model, however, was neither well calibrated nor well validated [Harrell, 2015]. Therefore, the Bayesian prediction model is preferable [Harrell, 2015].

Baseline characteristics of nitrous oxide sedations on session level			
	Success	Failure	Total
N (%)	744 (92.7)	59 (7.3)	803 (100)
Mean age (years ± SD)	7.1 (±2.9)	5.7 (±1.8)	7.0 (±2.8)
Age groups			
3-5-year-olds n (%)	257 (87.7)	36 (12.3)	293 (100)
6-12-year-olds n (%)	435 (95.2)	22 (4.8)	457 (100)
13-17-year-olds n (%)	52 (98.1)	1 (1.9)	53 (100)
Gender			
Female N (%)	341 (92.7)	27 (7.3)	368 (100)
Male N (%)	403 (92.6)	32 (7.4)	435 (100)
Treating dentist before and in nitrous oxide session			
Same dentist n (%)	542 (93.4)	38 (6.6)	580 (100)
Different dentist n (%)	202 (90.6)	21 (9.4)	223 (100)
Nitrous oxide session sequence; n (%)			
1st	442 (92.1)	38 (7.9)	480 (100)
2nd	190 (92.2)	16 (7.8)	206 (100)
3rd	60 (93.8)	4 (6.2)	64 (100)
4th – 14th	52 (98.1)	1 (1.9)	53 (100)
Year of use; n (%)			
2012	41 (83.7)	8 (16.3)	49 (100)
2013	64 (88.9)	8 (11.1)	72 (100)
2014	76 (86.4)	12 (13.6)	88 (100)
2015	114 (95)	6 (5)	120 (100)
2016	211 (95.5)	10 (4.5)	221 (100)
2017	238 (94.1)	15 (5.9)	253 (100)

TABLE 2 Baseline characteristics on session level of children treated under nitrous oxide sedation from 2012-2017 in the Department of Preventive and Pediatric Dentistry at the University of Greifswald (Germany).

The discrimination was also good in the Bayesian prediction model (c index = 0.72). Age was the most important predictor (Fig. 2), mainly because of the peak at 5 years of age (P = 0.041 for the departure from linearity). The year of use showed a clear learning effect. The remaining three predictors were negligible (Table 4).

Type of treatment	n (%)	
	Success n (%)	Failure n (%)
Extraction	737 (63.8)	
	685 (92.9)	52 (7.1)
Fillings	105 (9.1)	
	102 (97.1)	3 (2.9)
Fillings with anaesthetic	81 (7)	
	81 (100)	0
Pulpotomy	49 (4.2)	
	48 (98)	1 (2)
Endodontic	47 (4.1)	
	43 (91.5)	4 (8.5)
Stainless steel crown (SSC)	45 (3.9)	
	43 (95.6)	2 (4.4)
Modified Hall technique*	37 (3.2)	
	37 (100)	0
SSC in Hall technique (HT)	21 (1.8)	
	21 (100)	0
Fissure sealant	16 (1.4)	
	16 (100)	0
Direct pulp capping	6 (0.5)	
	6 (100)	0
Trepanation/access cavity	6 (0.5)	
	5 (83.3)	1 (16.7)
Slicing** (NRCT)	3 (0.3)	
	3 (100)	0
Frenectomy/electrosurgery	3 (0.3)	
	3 (100)	0
Total number of treatments	1156 (100)	
	1093 (94.6)	63 (5.4)

**modified Hall technique (proximal slice)*
*** opening the carious lesion with a burr as part of the non-restorative caries treatment*

TABLE 3 Numbers and frequencies of treatments performed under nitrous oxide sedation at the Department of Preventive and Pediatric Dentistry at the University of Greifswald between 2012 and 2017.

Side effects and complications

In 798 (99.4%) of the sessions no side effects or complication were recorded. In only 5 cases (0.6%) side effects were recorded: in 2 sessions the patient had a cutaneous allergic reaction likely due to the nitrous oxide mask, nausea was also recorded in 2 sessions and in 1 session a patient lost his consciousness/starting sleeping firmly during the treatment, but was awake 10 min later without any intervention.

Discussion

The use of sedation with nitrous oxide in dentistry in Germany has been a main point of discussion in the last years [Philippi-Höhne et al., 2013]. To our knowledge, this study is the first to describe the success rate and treatment spectrum for children under 18 years of age treated under nitrous oxide sedation in Germany and it shows clinically important factors correlated with the treatment success.

With an overall success rate of 92.7%, this study showed that nitrous oxide sedation is an effective treatment option in providing dental treatment in paediatric dentistry for pre-cooperative and anxious children. This matches the findings of other studies reporting a success rate of 83.9% [Bryan, 2002], 93% [Foley, 2005], 86.3% [Galeotti et al., 2016], and 93.7% [Hennequin et al., 2012].

In this study, the failure was divided in two categories: total and partial failure. Unlike in prospective design, it was not possible in this retrospective study to analyse if the level of sedation was adequate during the treatment. However, we assume that all patients who successfully completed the treatment under sedation had an appropriate level of sedation.

In 11 sessions (18.6%) the failures were due to the insufficient acceptance of the nitrous oxide mask, which could be potentially reduced by trying the mask on during the prior explanatory visit. A previous unpleasant dental experience while having an invasive treatment even under nitrous oxide or having a previous general anaesthesia could be the reason of not accepting the mask in spite of the proper preoperative explanation.

In relation to the age, the success rate for the treatment under nitrous oxide sedation substantially increased from preschool children with 87.7% to schoolchildren or adolescents with 95.2% and 98.1%, respectively, which is in agreement with Foley [2005]. In contrast to this, Hennequin et al. [2012] also reported a higher success rate for nitrous oxide sedation

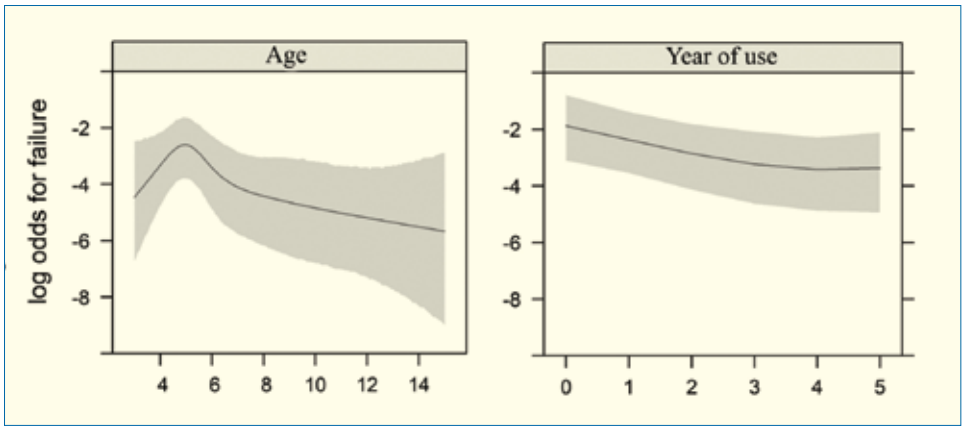

FIG. 2 Failure rate of nitrous oxide sedation for dental treatment in relation to age and the year of use.

				Conventional approach		Bayesian approach	
Variable	Value	Reference value	Global P value	Relative contribution: partial X^2 - degrees of freedom	Odds Ratio (95% confidence interval)	Relative contribution: relative explained variation (95% highest posterior density interval)	Odds Ratio (95% highest posterior density interval)
Age	5 years	8 years	0.0005	15.9	5.03 (2.21 – 11.45)	0.67 (0.29 – 0.86)	6.16 (2.26 – 18.0)
Gender	female	male	0.6301	-0.8	1.15 (0.62 – 1.86)	0.01 (0.00 – 0.13)	1.14 (0.60 – 2.18)
Same dentist	no	yes	0.1815	0.8	1.51 (0.83 – 2.75)	0.07 (0.00 – 0.25)	1.57 (0.81 – 3.10)
Session sequence	2	1	0.7126	-1.3	1.08 (0.60 – 1.97)	0.04 (0.00 – 0.26)	1.20 (0.60 – 2.43)
Year of use	2014	2017	0.0024	10.1	1.52 (0.71 – 3.23)	0.34 (0.05 – 0.59)	1.67 (0.73 – 4.08)

TABLE 4 Factors influencing the success rate of nitrous oxide sedation.

in dental treatment in preschool children (91.7%, n= 85) compared to other patient groups with about 95% success rates [Foley, 2005; Hennequin et al., 2012], while an Italian study found no statistically significant difference in relation to the mean age, but possibly due to a different categorisation of the age groups and different approach for analysis [Galeotti et al., 2016].

Although the 3–5-year-olds showed the highest failure rate for nitrous oxide sedation, a success rate of over 90% can be still interpreted as an encouraging result, as the application of nitrous oxide sedation in pre-school children can often allow easier treatment and avoid treatment under general anaesthesia. Compared to general anaesthesia, conscious sedation is considered to be safer [Averley et al., 2004; Lyratzopoulos and Blain, 2003]. This is especially relevant as preschool children are usually the largest group of patients in a specialised paediatric practice presenting high treatment needs which was reflected by the high caries levels (dmft = 5.8), pulp symptoms and low cooperation in this sample.

The year of use has a significant influence on the success rate of the nitrous oxide sedation as a clear learning effect was demonstrated. This increase is possibly due to increased number of trained personal and also to the increased experience when and how to use nitrous oxide sedation for dental treatment. In addition, advanced knowledge in behaviour management techniques like tell-show-do, enhancing control, etc. are essential for nitrous oxide sedation [AAPD, 2020], and these skill might also influence the success rates in nitrous oxide sedation. Changing dentist between appointments also increased the likelihood of failure slightly, possibly to the break in the relationship and trust.

Compared with the most recent epidemiological studies in Germany [Santamaria et al., 2019; Splieth et al., 2019], in which 1.7 dmft value was reported in 6–7-year-olds and 0.5 DMFT in 12-year-olds children, the population in this study had about 3-4 times higher dmft/DMFT values which reflects the situation of specialised paediatric dentistry. Also different types of dental procedures were performed under nitrous oxide sedation matching the findings by Galeotti et al. [2016] and Hennequin et al. [2012].

In spite of the potential limitations of a retrospective study such as uncomplete documentation or a case selection bias, the examined sample reflects a typical specialised paediatric setting with predominantly small children, high caries levels and mostly limited cooperation. Especially the "real life setting" with a very large sample size of 480 patients and 803 sedation sessions, the long-time span of 6 years and the wide range of different procedures and dentists performing the treatment) make the results highly plausible especially as main aspects and results were comparable to reports from the literature [Foley, 2005; Galeotti et al., 2016; Hennequin et al., 2012].

Conclusion

Nitrous oxide sedation is an advantageous a highly effective method for performing a great variety of invasive and potentially complex dental treatments for low-cooperative or anxious children, which may lead to a reduction of the use of general anaesthesia in dentistry. An increase in the success rate was found in older children and a clear learning effect was showed as the success increased with the year of use.

Acknowledgment

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Disclosure statement

No potential conflict of interest was reported by the authors.

Ethical approval

Approval for this clinical investigation was obtained from the Ethics Committee of the University of Greifswald (protocol number: BB 028/16, date: 15.03.2016).

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