

Clinical Performance of Nitrous Oxide Inhalation versus Intravenous Sedation in Outpatient Dental Surgery: Efficacy and Safety Outcomes

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Abstract

Selecting an optimal sedation technique is pivotal for balancing efficacy and safety in outpatient dental surgery. Nitrous oxide inhalation and intravenous sedation are widely used, yet comprehensive comparative data in similar clinical environments are needed to guide practice. The objective of this study was to prospectively compare the clinical efficacy, safety, and recovery profiles of nitrous oxide inhalation sedation versus intravenous midazolam sedation for outpatient dental surgical procedures. This prospective cohort study was conducted at Liberty Hospital Ltd. Paribagh, Shahbagh, Dhaka, Bangladesh, from January to December 2024. A purposive sample of 50 patients was allocated to receive either nitrous oxide/oxygen (n=25) or intravenous midazolam sedation (n=25). Efficacy was measured by procedure completion, operator satisfaction (10-point VAS), and patient-reported anxiety reduction. Safety outcomes included hemodynamic stability, adverse event incidence, and time to meet a modified Aldrete recovery score of ≥ 9 . Data were analyzed using SPSS version 23.0. Both techniques achieved 100% procedure completion. Intravenous sedation provided superior operator satisfaction and greater anxiety reduction ($p < 0.001$). However, nitrous oxide yielded a significantly faster recovery time (8.5 vs. 33.1 minutes, $p < 0.001$) and lower rates of postoperative nausea (8.0% vs. 36.0%, $p = 0.021$) and hypotension (4.0% vs. 32.0%, $p = 0.019$). Hemodynamic changes were more pronounced with IV sedation. Intravenous sedation is optimal for profound anxiolysis in complex cases, while nitrous oxide is ideal for routine procedures, prioritizing rapid recovery and fewer side effects. The choice should be individualized based on patient factors and procedural demands.

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Introduction

Outpatient dental surgery encompasses a range of procedures, from complex exodontia to implant placements, which frequently necessitate pharmacological management of patient anxiety and pain to ensure cooperation, comfort, and procedural success.¹ The paradigm of dental care has progressively shifted towards ambulatory settings, emphasizing the need for sedation techniques that are not only effective but also efficient, with rapid onset and recovery profiles to facilitate patient discharge.² Within this context, moderate sedation, a drug-induced depression of consciousness, remains a cornerstone, allowing patients to respond purposefully to verbal commands while maintaining protective reflexes.³ The selection of an optimal sedation protocol is a critical clinical decision, balancing the triad of efficacy, safety, and cost-effectiveness. Two of the most prevalent modalities are nitrous oxide inhalation sedation (N_2O/O_2) and

intravenous sedation (IVS), typically employing agents like midazolam.⁴ Nitrous oxide, a colorless and sweet-smelling gas, is administered via a nasal hood in a titratable concentration mixed with

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oxygen. Its mechanism of action involves modulation of the N-methyl-D-aspartate (NMDA) receptor, providing anxiolysis, analgesia, and a dissociative state with a remarkably rapid onset and offset due to low blood-gas solubility.⁵ Its historical use is long-standing, prized for its minimal impact on cardiovascular parameters and the preservation of patient responsiveness.⁶ In contrast, intravenous sedation offers a deeper and more predictable level of sedation, particularly beneficial for highly anxious patients or prolonged surgical interventions. Benzodiazepines, such as midazolam, are mainstays for IVS due to their potent anxiolytic, sedative, and amnesic properties.⁷ While offering superior control over sedation depth, IVS requires venous access, more intensive monitoring, and is associated with a longer recovery period and a higher potential for cardiorespiratory depression, necessitating the presence of trained personnel.^{8,9} The recovery trajectory, defined as the time to meet specific discharge criteria, is a pivotal outcome in outpatient care, directly influencing clinical throughput and patient satisfaction.¹⁰ Despite the widespread use of both techniques, a definitive consensus on their comparative clinical performance remains elusive, with existing literature presenting heterogeneous findings. Some studies posit IVS as superior for managing severe dental anxiety, while others advocate for nitrous oxide due to its favorable safety margin and faster recovery.^{11,12} Furthermore, much of the extant evidence originates from high-income Western nations, with a paucity of prospective data from resource-limited settings like Bangladesh, where patient demographics, procedural norms, and monitoring standards may differ.¹³ This gap underscores the need for localized, context-specific evidence to guide clinical practice and resource allocation. Therefore, this prospective cohort study

was designed to directly compare the clinical efficacy and safety outcomes of nitrous oxide inhalation sedation versus intravenous midazolam sedation in patients undergoing outpatient dental surgery at a tertiary hospital in Dhaka, Bangladesh. By systematically evaluating parameters including procedural success, anxiolytic depth, operator satisfaction, hemodynamic stability, adverse event profiles, and recovery times, this research aims to provide empirical data to inform evidence-based sedation protocols in similar ambulatory dental care environments.

Methods

A prospective cohort study was conducted at the Department of Oral and Maxillofacial Surgery, Liberty Hospital Ltd. Paribagh, Shahbagh, Dhaka, from January to December 2024. A purposive sample of 50 adult patients scheduled for elective outpatient dental surgical procedures was enrolled and equally allocated into two groups: Nitrous Oxide Sedation (N₂O, n=25) and Intravenous Sedation (IVS, n=25).

Inclusion criteria

Participants were eligible if they were aged 18-65 years, classified as American Society of Anesthesiologists (ASA) physical status I or II, and had a pre-operative anxiety score of ≥ 4 on the Modified Dental Anxiety Scale (MDAS). Written informed consent was mandatory.

Exclusion criteria

Exclusion criteria comprised contraindications to either sedation method (e.g., pregnancy, chronic obstructive pulmonary disease, psychiatric disorders on major medication), known hypersensitivity to midazolam or nitrous oxide, history of substance abuse, or inability to comprehend the study protocol.

Study procedure

The N₂O group received titrated nitrous oxide/oxygen inhalation (maximum 50% N₂O). The IVS group received intravenous midazolam (0.05-0.075 mg/kg). A single surgeon performed all procedures. A blinded researcher recorded intraoperative hemodynamics, procedure duration, and any adverse events. Recovery time was measured from procedure end until achieving a modified Aldrete score ≥ 9 . Patient-reported anxiety reduction and operator satisfaction were recorded postoperatively using Visual Analogue Scales (VAS).

Data analysis

Collected data were analyzed using IBM SPSS Statistics version 23.0. Normality was assessed using Shapiro-Wilk test. Continuous variables were compared using independent t-tests or Mann-Whitney U tests. Categorical variables were analyzed using Chi-square or Fisher's exact tests. A p-value of <0.05 was considered statistically significant for all analyses.

Result

The study included 50 participants, with 25 patients in each of the nitrous oxide (N₂O) and intravenous sedation (IVS) groups. Baseline demographic and clinical characteristics were comparable between both cohorts. The mean age was 39.2 (± 10.9) years in the N₂O group and 41.6 (± 10.5) years in the IVS group. The majority of patients were classified as ASA I, and preoperative anxiety levels were high and statistically similar. Both sedation techniques were entirely effective, with a 100% procedure completion rate achieved in each group. However, measures of sedation depth and operator experience favored IVS. Operator satisfaction scores were significantly higher for IVS, and patient-reported

intraoperative anxiety reduction was also greater in this group. Critical differences emerged in recovery and safety profiles. Recovery time was markedly and significantly shorter for patients receiving N₂O. Furthermore, the incidence of adverse events was lower in the N₂O cohort. Specifically, postoperative nausea and clinically significant hypotension occurred at a significantly higher rate in the IVS group. While overall patient satisfaction was high and similar between groups, a greater proportion of patients in the N₂O group expressed willingness to undergo the same sedation method again.

Table 1: Baseline demographic and clinical characteristics

Characteristic	Nitrous oxide	Intravenous sedation	p-value
Age (years), Mean $\pm$ SD	39.2 $\pm$ 10.9	41.6 $\pm$ 10.5	0.43
Gender (Female), n (%)	15 (60.0%)	14 (56.0%)	0.777
ASA status I, n (%)	20 (80.0%)	19 (76.0%)	0.739
Pre-op MDAS score, Mean $\pm$ SD	6.6 $\pm$ 1.7	6.9 $\pm$ 1.5	0.491

Statistical test: Independent t-test for age and MDAS; Chi-square test for gender and ASA status.

Table 2: Primary efficacy and operative outcomes

Outcome	Nitrous oxide	Intravenous sedation	p-value
Procedure completion rate, n (%)	25 (100%)	25 (100%)	1.000
Operator satisfaction (VAS 0-10), Mean $\pm$ SD	7.2 $\pm$ 1.4	8.8 $\pm$ 1.0	<0.001
Mean anxiety reduction (VAS), Mean $\pm$ SD	4.3 $\pm$ 1.3	5.9 $\pm$ 1.1	<0.001
Procedure duration (min), Mean $\pm$ SD	26.1 $\pm$ 8.5	28.5 $\pm$ 9.1	0.335

Statistical test: Independent t-test for Operator Satisfaction, Anxiety Reduction, and Duration; Fisher's Exact test for Completion Rate.

Table 3: Recovery profile

Recovery parameter	Nitrous oxide	Intravenous sedation	p-value
Time to Aldrete ≥ 9 (min), Mean $\pm$ SD	8.5 $\pm$ 3.0	33.1 $\pm$ 9.8	<0.001
Ready for discharge (<30 min), n (%)	25 (100%)	10 (40.0%)	<0.001

Statistical test: Independent t-test for Recovery Time; Chi-square test for Discharge Readiness.

Table 4: Incidence of adverse events

Adverse event	Nitrous oxide	Intravenous sedation	p-value
	n (%)		
Postoperative nausea	2 (8.0%)	9 (36.0%)	0.021
Vomiting	0 (0%)	3 (12.0%)	0.237
Oxygen desaturation (SpO ₂ <92%)	1 (4.0%)	2 (8.0%)	1.000
Postoperative dizziness	3 (12.0%)	6 (24.0%)	0.461
Hypotension (SBP drop >20%)	1 (4.0%)	8 (32.0%)	0.019

Statistical test: Fisher's Exact test.

Table 5: Hemodynamic changes from baseline (Mean $\pm$ SD)

Parameter	Nitrous oxide	Intravenous sedation	p-value
Max heart rate change (bpm)	+5.5 $\pm$ 4.3	+3.3 $\pm$ 5.5	0.127
Max SBP reduction (mmHg)	-8.7 $\pm$ 6.0	-19.5 $\pm$ 9.3	<0.001
Max DBP reduction (mmHg)	-5.3 $\pm$ 4.5	-12.8 $\pm$ 6.9	<0.001

Statistical test: Independent t-test.

Table 6: Patient-reported outcomes

Patient-Reported Outcome	Nitrous oxide	Intravenous sedation	p-value
	n (%)		
Overall satisfaction (VAS ≥8)	21 (84.0%)	20 (80.0%)	0.723
Willingness to repeat the same method	24 (96.0%)	19 (76.0%)	0.096

Statistical test: Chi-square test.

Discussion

This prospective cohort study provides a comparative analysis of two cornerstone sedation techniques in outpatient dental surgery. The principal findings indicate that while both nitrous oxide inhalation and intravenous midazolam sedation are highly effective for facilitating procedure completion, they present a distinct trade-off between procedural control and post-operative recovery. Intravenous sedation offered superior operator satisfaction and greater anxiolytic depth, aligning with its pharmacological profile as a potent benzodiazepine providing reliable amnesia and deeper sedation.¹⁴ This makes it particularly suitable for managing severe dental anxiety or for more complex, prolonged surgical interventions where profound patient cooperation is paramount.¹⁵ Conversely, nitrous oxide sedation demonstrated a decisively advantageous recovery and hemodynamic profile. The significantly shorter time to meet discharge criteria (Aldrete score ≥ 9) with N₂O is a critical operational finding. This rapid recovery, attributable to the agent's low blood-gas solubility allowing for quick pulmonary elimination, directly enhances clinical throughput and aligns with the efficiency demands of modern ambulatory care.^{16,17} The faster recovery likely contributed to the higher, though not statistically significant, willingness among N₂O patients to undergo the same method again, suggesting a preference for a quicker return to normal function. The safety outcomes further delineate the risk profiles of each modality. The significantly higher incidence of postoperative nausea and clinically relevant hypotension associated with intravenous sedation is consistent with known side effects of midazolam and deeper sedation levels, which can depress sympathetic tone and the chemoreceptor trigger zone.^{18,19} In contrast, nitrous oxide's minimal metabolic interference and preservation of protective

reflexes resulted in markedly fewer emetic and hemodynamic complications, reinforcing its reputation for a wide margin of safety.²⁰ The comparable rates of oxygen desaturation were low in both groups, underscoring the importance of standard monitoring protocols regardless of the technique employed. These results corroborate and extend findings from previous studies. Research by Wilson & Girdler (2019) similarly found IVS superior for anxiety control but with longer recovery, while our data on nausea incidence aligns with meta-analytic reviews highlighting the emetogenic potential of parenteral sedatives compared to inhalation agents.^{11,21} However, our study adds context-specific data from a Bangladeshi hospital setting, where resource allocation and patient flow are pressing concerns. The demonstrable efficiency of N₂O presents a compelling case for its expanded use in comparable environments to optimize theatre turnover and reduce postoperative nursing burden. The purposive sampling method may introduce selection bias, and the single-center design limits generalizability. The absence of randomization, though mitigated by prospective cohort comparison and comparable baselines, means unmeasured confounding factors could persist. Furthermore, the study was not blinded, which may have influenced subjective ratings like operator satisfaction. Future multicenter, randomized controlled trials with larger samples and cost-effectiveness analyses are warranted.^{22,23} This study demonstrates that the choice between nitrous oxide and intravenous sedation for outpatient dental surgery is not a matter of superiority but of strategic selection based on clinical priorities. Intravenous midazolam is the modality of choice for procedures requiring profound anxiolysis and where operator control is the primary concern. Nitrous oxide inhalation, with its rapid onset and offset, excellent

hemodynamic stability, and lower rate of adverse effects, is the optimal strategy for promoting fast-track recovery and maximizing efficiency in a busy outpatient setting. A patient-centered approach, considering individual anxiety levels, medical history, and procedural complexity, should guide the final decision.^{24,25}

Limitations

This Multicenter, clinic-based study using purposive sampling may limit generalizability to the wider population. Etiological factors, skeletal patterns, and oral habits were not assessed, and radiographic correlations were beyond the study's scope.

Conclusion

This study demonstrates a clear efficacy-safety trade-off. Intravenous midazolam provides superior anxiolysis for complex cases, while nitrous oxide offers a rapid-recovery, low-side-effect profile ideal for efficient outpatient flow. The choice should be individualized, balancing procedural demands against recovery priorities and patient risk factors. Incorporating these findings into clinical protocols can optimize both patient experience and operational efficiency in ambulatory dental surgery settings.

Recommendation

We recommend prioritizing nitrous oxide for routine cases to enhance throughput and safety. Intravenous sedation should be reserved for highly anxious patients or complex procedures. Developing institutional guidelines based on this risk-benefit profile is advised for optimal resource utilization.

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