Nitrous Oxide/Oxygen Effect on IANB Injection Pain and Mandibular Pulpal Anesthesia in Asymptomatic Subjects

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The inferior alveolar nerve block (IANB) does not always result in successful pulpal anesthesia. Nitrous oxide may increase the success of the IANB. The purpose of this investigation was to study the effect of nitrous oxide/oxygen (N_2O/O_2) on IANB injection pain and mandibular pulpal anesthesia in asymptomatic subjects. One hundred five asymptomatic subjects received an IANB after the administration of N_2O/O_2 or room air/oxygen (air/O_2) at 2 separate appointments. After the IANB, subjects rated their level of pain for each phase of the injection (needle insertion, needle placement, and solution deposition) using a Heft Parker visual analog scale. Pulpal anesthesia was evaluated with an electric pulp tester for 60 minutes. The mean pain rating for all 3 injection phases showed a statistically significant reduction in pain when N_2O/O_2 was used compared with Air/O_2 ($P < .05$). Odds ratios demonstrated a statistically significant increase in IANB success for the N_2O/O_2 group compared with the air/O_2 group. N_2O/O_2 administration statistically decreased pain for all 3 injection phases of the IANB. In addition, nitrous oxide statistically increased the likelihood of pulpal anesthesia for posterior mandibular teeth. However, the incidence of pulpal anesthesia was not 100%.

Key Words: Nitrous oxide; Pulpal anesthesia; Injection pain; Inferior alveolar nerve block; Local anesthesia.

Effective local anesthesia is a basic principle of dentistry. One of the most used local anesthetic techniques, the inferior alveolar nerve block (IANB), does not always result in successful pulpal anesthesia. Failure rates for pulpal anesthesia after an IANB have been reported to be between 10–39% in asymptomatic subjects.[1] Previous investigations have evaluated various approaches to help improve the success of pulpal anesthesia following an IANB, including increased anesthetic volumes, addition of buffering agents, and orally administered anxiolytics, all with limited success.[1–5]

Nitrous oxide/oxygen (N_2O/O_2) may be helpful for increasing the success of the IANB. Authors outside the field of dentistry have found better analgesic results with the use of nitrous oxide.[6–8] In a study involving patients with symptomatic irreversible pulpitis, Stanley et al[9] found a statistically significant increase in anesthetic success when using N_2O/O_2 as an anesthetic adjunct as compared with using room air/oxygen (air/O_2). The positive results associated with using nitrous oxide in patients with symptomatic irreversible pulpitis were further demonstrated in a recent nitrous oxide/intranasal ketorolac model.[10] It is apparent that nitrous oxide is capable of providing useful analgesia, and historical studies have reported that 30% nitrous oxide is equivalent to approximately 10–15 mg morphine.[11–14]

Previous investigations have focused on the evaluation of painful teeth that need endodontic treatment and not asymptomatic teeth that may require more routine dental treatment such as direct or indirect restorations. The purpose of this investigation was to study the effects of N_2O/O_2 on IANB injection pain and mandibular pulpal anesthesia success in asymptomatic subjects with normal healthy teeth.

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MATERIALS AND METHODS

A total of 105 subjects 18 years and older and in good health (American Society of Anesthesiologists [ASA] class I or II) as determined by a health history and oral questioning were included in the study. Exclusion criteria included subjects younger than 18 years, allergy to local anesthetics or nitrous oxide, a history of significant medical problems (ASA III or greater), recent consumption of central nervous system depressants (including alcohol or any analgesic medications), nasopharyngeal obstructions, respiratory infections, sinusitis, pregnancy, lactating, or unable to provide informed consent. Written informed consent, HIPAA authorization, and medical history were obtained from each subject. Approval for this study was obtained from The Ohio State University Human Subjects Review Committee.

Subjects received an IANB at 2 separate appointments spaced at least 1 week apart while either air/O_2 or N_2O/O_2 was administered in a double-blind crossover design. A random-number table (random.org) determined the study arm assignment (ie, air/O_2 or N_2O/O_2) for the initial appointment and the anatomical side of the IANB for each subject. To minimize variability, the IANB was repeated on the same side during the second appointment while the patient was assigned to the opposite study arm.

Each subject completed a Corah dental anxiety scale[15] at the start of the first visit to rate his or her level of anxiety.

The test teeth chosen for the study were the mandibular first and second premolars and molars. The contralateral canine served as the unanesthetized control to ensure proper functioning of the electric pulp tester (EPT; Analytic Technology Corp, Redmond, Wash) and appropriate subject response. At the beginning of the appointment prior to any anesthetic administration, a clinical examination was performed to ensure that all study teeth were free of caries, large restorations, or periodontal disease and that none had histories of trauma or sensitivity. The teeth and control canine were tested 3 times with the EPT to record baseline vitality. After isolating the tooth with cotton rolls and drying with gauze, toothpaste (Colgate Total, Colgate-Palmolive Company, New York, NY) was applied to the EPT probe tip, which was placed on the buccal surface midway between the gingival margin and the occlusal edge of each tooth being tested. The current rate on the EPT was set to increase from zero (0) to the maximum output (80) over 25 seconds. The numeric readout at initial sensation was recorded. All test teeth in the experiment were confirmed to be vital by EPT testing. Trained research personnel performed all pre- and postinjection tests.

The inhalational agents (either N_2O/O_2 or air/O_2) were administered for 10 minutes prior to the IANB with a scented nasal mask (Accutron, Inc, Phoenix, Ariz) and nitrous oxide machine (McKesson Equipment Company, Chesterfield, UK). This was preceded by the administration of supplemental oxygen (3 L/min) for 5 minutes before starting the study inhalational agents. A doctor not involved in the IANB or pulp testing administered the inhalational agents and remained present throughout the duration of use. When administering the air/O_2 mixture, the scented nasal mask was placed in position, but the air-intake valve was left open while oxygen was delivered at approximately 3 L/min, creating a mixture of oxygen diluted with air. This allowed the subject to still experience the feeling and sounds of gas flowing through the nasal mask. During the IANB and pulp testing, the hub of air intake unit was covered with a round molded dental mask (Mydent International, Hauppauge, NY), which was trimmed to the size of the intake hub. In addition, the nitrous oxide machine was directed away from the operator and patient, so it was visible only to the doctor administering the inhalation regimen.

The N_2O/O_2 was titrated over a 5-minute period until a 30–50% concentration of nitrous oxide was achieved. The subject was questioned every 30 seconds by the doctor administering the inhalational mixture for appropriate signs of sedation. Once a feeling of lightheadedness, followed by a tingling sensation in the arms or legs, or a feeling of warmth, floating, or heaviness was reported (30–50% concentration), the subject was maintained at that level for 5 minutes prior to the local anesthetic injection. For the air/O_2 mixture, the doctor mimicked the adjustment of the nitrous oxide flow rate and questioned the subject every 30 seconds for 5 minutes. The patient also rated their perceived level of sedation on a 100-mm visual analog scale (VAS; 0 = no sedation to 100 = complete sedation) prior to local anesthetic injection at each appointment. When the experiment was complete, the patient was placed back on supplemental oxygen (3 L/min) for 5 minutes.

At each of the 2 visits, a standard IANB[16] was performed with 1.8 mL of 2% lidocaine with 1:100,000 epinephrine administered with a 27-gauge 1½-inch needle attached to a standard aspirating dental syringe. Before the injection, each subject was shown a Heft Parker VAS[17] and instructed to rate their pain for each phase of the injection: needle insertion, needle placement, and solution deposition (Figure 1). The subject was verbally informed during each procedural step.

For the conventional IANB, the needle was inserted following landmarks as described by Jorgensen and

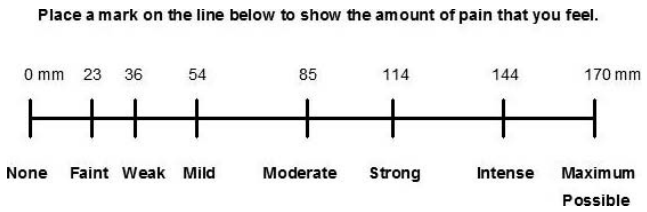

Figure 1. Heft-Parker visual analog scale. Note: The millimeter markings were not present on the subject's form but the descriptors were.

Hayden (needle insertion).[16] The needle then was advanced to the target site over 6 seconds without any anesthetic being administered (needle placement). Following negative aspiration, 1.8 mL of the 2% lidocaine with 1:100,000 epinephrine was deposited over a 1-minute time period (solution deposition). The first author (B.K.) administered all injections. Immediately after the injection, each subject rated the pain for each injection phase using the VAS by placing a mark on the scale where it best described their pain level. To interpret the data, the VAS was divided into 4 categories. No pain corresponded to 0 mm on the scale. Mild pain was defined as >0 mm and ≤54 mm and included the descriptors of faint, weak, and mild pain. Moderate pain was defined as >54 mm and <114 mm and included no descriptors. Severe pain was defined as ≥114 mm and included the descriptors of strong, intense, and maximum possible.

At 1 minute after the IANB, the second and first molars were pulp tested followed by the second and first premolars 1 minute later. At 4 minutes, the contralateral canine was pulp tested, and the subject was evaluated for lip numbness. This cycle of testing was repeated every 4 minutes for 60 minutes. At every fourth cycle, the control tooth (contralateral canine) was tested by a pulp tester without batteries to check for subject reliability. Subjects who responded positively to an inactivated pulp tester were considered unreliable, and their data were removed from the study. No subjects were excluded for this reason. If profound lip numbness was not recorded within 15 minutes, the block was considered unsuccessful and the patient was reappointed. This occurred in 4 subjects, 2 from the N_2O/O_2 group and 2 from the air/O_2 group. All testing was stopped at 60 minutes postinjection.

No response from the subject at the maximum output of the EPT (80 reading) was used as the criterion for successful pulpal anesthesia. Odds ratios were calculated comparing successful pulpal anesthesia for each tooth type between treatment methods (N_2O/O_2 and air/O_2) for the duration of the hour.

Statistical Analysis

Comparisons of injection pain were completed using repeated-measures, factorial analysis of variance with inhalation method (N_2O/O_2 and air/O_2) and injection phase (insertion, placement, and deposition) as the factors. Post hoc analysis was performed using the Tukey–Kramer test. Differences between treatment modalities (N_2O/O_2 vs air/O_2) were assessed using a repeated-measures logistic regression. Sedation values were compared using a Wilcoxon signed-rank test. The statistical package used for the analysis was SAS. Comparisons were considered significant at $P < .05$.

An a priori power analysis was performed to determine a sample size of 105 subjects would be required to demonstrate an odds ratio of 2.5 for N_2O/O_2 versus air/O_2 with a power of .80 and a nondirectional alpha risk of .05.

RESULTS

One hundred-five subjects participated in this study, 53 women and 52 men, with 53 right and 52 left IANB administered total. The patient age range was 19 to 37 years, with a mean age of 25 years. The average Corah dental anxiety score was 5, which corresponded to a low dental anxiety rating.[15]

Mean pain scores for the N_2O/O_2 group were significantly lower than the air/O_2 group for each of the 3 injection phases ($P < .05$; Table 1). Most subjects had pain score ratings of mild or moderate for each of the 3 injection phases regardless of the study group. The pain score ratings (none, mild, moderate, severe) data for the 2 study groups for the 3 injection phases are presented in Table 1 and Figure 2.

The odds ratios (likelihood of achieving pulpal anesthesia) for success of the IANB for the N_2O/O_2 group compared with the air/O_2 group are reported in Table 2. The N_2O/O_2 group had a higher likelihood of IANB success for all 4 tooth types as compared with the air/O_2 group, which was statistically significant ($P <$ .05). The highest incidence of pulpal anesthesia (EPT reading of 80) for the N_2O/O_2 group and air/O_2 group is reported in Table 2 and Figure 3. The highest incidence of pulpal anesthesia was not analyzed statistically because the odds ratio determined differences in success but was included to inform the reader of the highest incidence of pulpal anesthesia for the 2 groups.

The mean sedation rating for the N_2O/O_2 group was 50 ± 23 mm in comparison with 8 ± 11 mm for the air/O_2 group, which was a statistically significant difference ($P < .05$).

Table 1. Pain Ratings for the 3 Injection Phases Using Nitrous Oxide/Oxygen or Air/Oxygen

	None	*Mild*	*Moderate*	*Severe*	*Mean ± SD, mms*
Needle insertion*					
N_2O/O_2	5% (5/105)	66% (69/105)	29% (30/105)	1% (1/105)	42 ± 25
air/O_2	1% (1/105)	45% (47/105)	49% (52/105)	5% (5/105)	55 ± 28
Needle placement*					
N_2O/O_2	9% (10/105)	59% (62/105)	31% (33/105)	0% (0/105)	40 ± 26
air/O_2	2% (2/105)	40% (42/105)	52% (55/105)	6% (6/105)	59 ± 32
Solution deposition*					
N_2O/O_2	14% (15/105)	62% (65/105)	23% (24/105)	1% (1/105)	33 ± 29
air/O_2	5% (5/105)	58% (61/105)	33% (35/105)	4% (4/105)	47 ± 33

* $P < .05$, statistically significant difference between the 2 study groups as assessed by the means.

DISCUSSION

For needle insertion, needle placement, and solution deposition, the administration of N_2O/O_2 significantly decreased pain when compared with air/O_2 (Table 1; Figure 2). However, moderate pain (23–31%) was still reported in all 3 phases for the N_2O/O_2 group (Table 1). Although various methods have been used to reduce injection pain, such as topical anesthetics,[18,19] buffering,[3,20–22] and 2-stage injections,[23] they have had only limited success. Further research needs to address ways to reduce pain from an IANB injection.

The results of the current study demonstrated that nitrous oxide functions as an analgesic and increases the likelihood of anesthesia for posterior mandibular teeth in this asymptomatic model (Table 2; Figure 3). Although the incidence of pulpal anesthesia was higher with the N_2O/O_2 mixture, it was not 100%. Nusstein et al[1] found that the success rates (no response to 2 consecutive EPT readings of 80) of the IANB in 462 asymptomatic subjects were 65% for second molars, 51% for first molars, and 58–60% for premolars. Although the current results of this study had lower success rates, probably because of individual variations

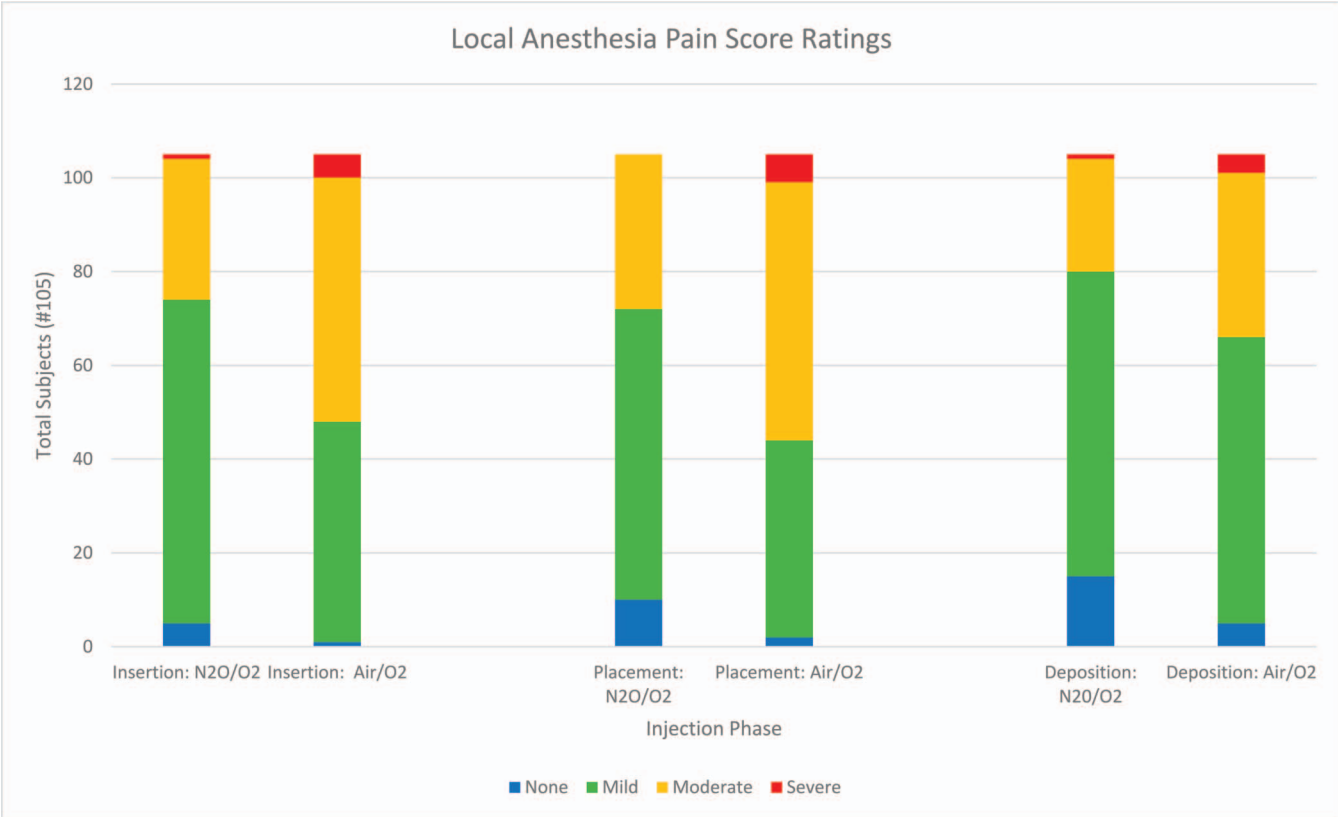

Figure 2. Pain score ratings for the 3 injection phases of the inferior alveolar nerve block.

Table 2. Odds Ratio Estimates and Highest Percentage of Success for Each Tooth

Tooth Group	*Highest % Success**	*N_2O/O_2 Versus Air/O_2 Odds Ratio*	*95% Confidence Intervals*
First molar		2.65	1.90 – 3.69
N_2O/O_2	39%		
Air/O_2	30%		
Second molar		1.99	1.47 – 2.70
N_2O/O_2	68%		
Air/O_2	58%		
First premolar		3.78	2.47 – 5.78
N_2O/O_2	32%		
Air/O_2	22%		
Second premolar		1.87	1.34 – 2.62
N_2O/O_2	38%		
Air/O_2	30%		

* All odds ratios were significant ($P < .05$) for each tooth. The highest incidence of pulpal anesthesia (electric pulp tester 80 readings) were not analyzed statistically because the odds ratio determined differences in success but were included to inform the reader of the highest incidence of pulpal anesthesia for the 2 groups.

in populations, overall, supplemental injections would be necessary to ensure pulpal anesthesia in most posterior mandibular teeth. A complete explanation of the causes of failure and remedies to local anesthesia of the IANB (accuracy of injection, cross innervation, needle bevel orientation, volumes of anesthesia, epinephrine concentrations, articaine versus lidocaine, prilocaine versus mepivacaine, buffering, preemptive medications, etc) have been explained in detail in *Successful Local Anesthesia*,[24] and the reader is directed to this text. Previous research on the IANB shows that using an additional buccal or labial infiltration of articaine,[25,26] intraosseous administration,[27,28] or intraligamentary injections[29] results in an increased success rate for this block and would be useful even if nitrous oxide/oxygen is administered clinically.

The dosages of N_2O/O_2 administered for this study were based on previous reports regarding nitrous oxide use and its effects on anesthesia and analgesia.[9,10,30] As stated previously, Stanley et al[9] found that the administration of 30–50% nitrous oxide resulted in a statistically significant increase in IANB success for mandibular symptomatic teeth diagnosed with irreversible pulpitis. Likewise, Stentz et al[10] further supported this finding that the administration of N_2O/O_2 at concentrations of 30–50% increased IANB success in patients diagnosed with symptomatic irreversible pulpitis. In a pediatric population premedicated with ibuprofen, Chompu-inwai et al[30] reported that nitrous oxide at concentrations between 30 and 50% could increase the success of pulpal anesthesia in permanent teeth diagnosed with irreversible pulpitis. Other studies have suggested higher doses (50–70%) of nitrous oxide be used.[31,32] However, unwanted side effects including excitement, nausea, restlessness, and dysphoria have been reported with these doses.[31,32]

In dentistry, nitrous oxide is used routinely to produce minimal to moderate sedation for anxious patients. Some authors[33] have suggested that the sedative effects of nitrous oxide would result in a more relaxed patient, reacting to stimuli more slowly and possibly less specifically to pain. In the current study, the effects of N_2O/O_2 resulted in a significantly higher patient sedation rating than air/O_2 (50 ± 23 mm vs 8 ± 11 mm) as would be expected. However, it was unexpected to find that patients rated any sedative effects at all for the air/O_2 mixture, which likely reflected a placebo effect.

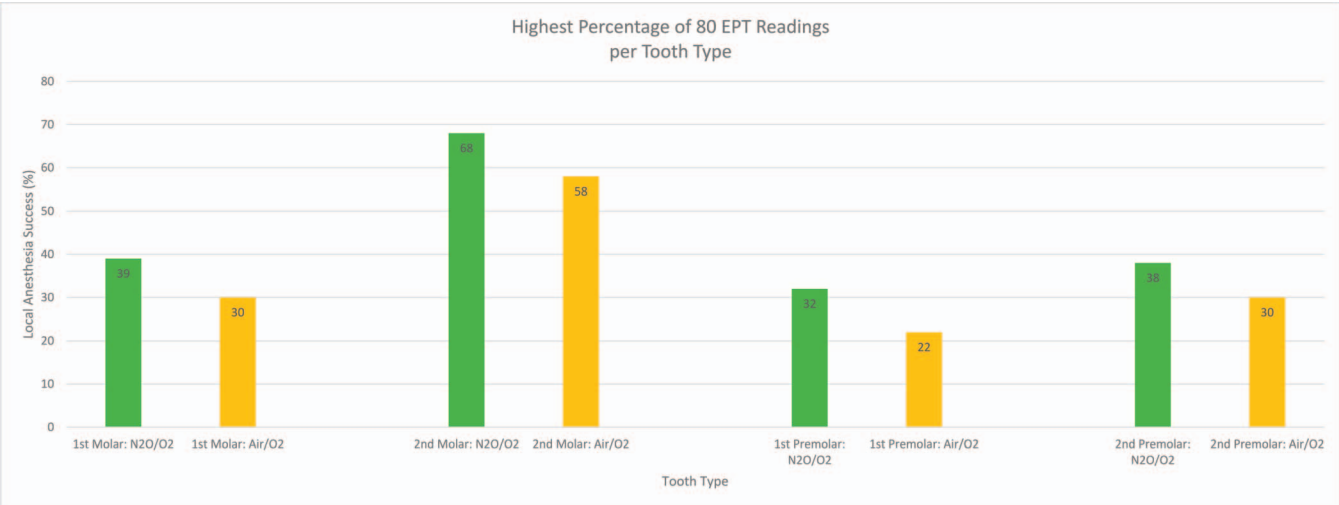

Figure 3. The highest incidence of 80 electric pulp tester readings for the molars and premolars.

CONCLUSIONS

We concluded that N_2O/O_2 administration led to a statistically significant decrease in pain during all 3 injection phases of the IANB when compared with air/O_2. In addition, nitrous oxide statistically increased the likelihood of pulpal anesthesia for posterior mandibular teeth. However, the incidence of pulpal anesthesia was not 100%.

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