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Original Article

# Effect of dental anxiety on the success of inferior alveolar nerve block in symptomatic irreversible pulpitis: A prospective clinical study

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**KEYWORDS**
Dental anxiety;
Local anesthesia;
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Cortisol

**Abstract** *Background/purpose:* Successful anesthesia in symptomatic irreversible pulpitis (SIP) presents a clinical challenge, with psychological factors such as dental anxiety potentially affecting outcomes.This clinical trial aimed to evaluate dental anxiety's impact on the success of inferior alveolar nerve block (IANB) in mandibular molars diagnosed with SIP under standardized preoperative pain conditions.
*Materials and methods:* In total, 52 systemically healthy patients with symptomatic irreversible pulpitis in mandibular first molars were included and categorized into low (MDAS $\leq$10) and moderate-to-high (MDAS $\geq$11) anxiety groups based on modified dental anxiety scale (MDAS) scores. All participants received IANB with 1.8 mL of 4 % articaine with epinephrine (1:100,000), followed by supplemental buccal-lingual infiltration. Anesthetic success was defined as a VAS score $\leq$3 during access cavity preparation. Salivary cortisol concentrations, pulse rate, and oxygen saturation were also recorded. The statistical analyses included independent t-tests, Pearson correlation, binary logistic regression, and multiple correspondence analysis.
*Results:* Anesthesia success was significantly higher in the low anxiety group (84.2 %) than the high anxiety group (15.8 %) ($P < 0.001$). The high anxiety group had elevated salivary cortisol levels and pulse rates ($P < 0.05$). Logistic regression identified salivary cortisol as the only independent predictor of anesthetic failure ($P = 0.010$).
*Conclusion:* Dental anxiety was associated with lower success rates of local anesthesia in

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patients with SIP. Increased salivary cortisol levels were observed in anesthetic failures, indicating its potential relevance as a supportive biomarker; however, these findings should be interpreted with caution, considering that operator proficiency and technique also play critical roles in outcomes.


## Introduction

Effective pain management is fundamental for patient comfort and favorable endodontic outcomes.[1] Achieving profound anesthesia in symptomatic irreversible pulpitis (SIP) remains a major clinical challenge, particularly in mandibular molars, where higher rates of anesthetic failure and postoperative pain are reported.[2] Although numerous anesthetic techniques, devices, and solutions have been investigated to mitigate pain during root canal procedures,[1,3] the inferior alveolar nerve block (IANB) remains the most frequently used method, yet its failure rate ranges from 43 % to 83 %.[4] Such failure has been attributed to pulpal inflammation, anatomical variations, and psychological factors such as dental anxiety, with peripheral and central sensitization representing the primary mechanisms underlying IANB failure.[5,6]

Dental anxiety is a stress response to actual or perceived threats and has psychological and physiological components, triggering tachycardia, hypertension, hyperglycemia, mydriasis, hyperthermia, and hypercholesterolemia, and activating the hypothalamic-pituitary-adrenal (HPA) axis, which produces cortisol[7] It is a common condition, with its adult prevalence rates ranging between 3 % and 16 %.[8,9] To assess patients' tendency to perceive dental treatment as threatening and fear-inducing, epidemiological and clinical studies widely use the dental anxiety scale (DAS).[10] Humphris et al.[11] standardized the scale's response options and added a fifth item focused on injection-related anxiety—the most significant fear trigger for many—thereby developing the modified dental anxiety scale (MDAS), which was adapted into Turkish and validated in 2005.[12] A study that investigated dental anxiety's effect on pain perception found that anxiety and pain may become indistinguishable in acute pain-related clinical situations—anxiety lowers the pain threshold and causes normally non-painful stimuli to be perceived as painful.[13]

Numerous studies have investigated the success of anesthesia in teeth diagnosed with irreversible pulpitis.[1,14] Substantial research has also reported pain's impact on dental anxiety.[15,16] While some studies have suggested that anesthetic failure may produce dental anxiety, research on dental anxiety's effect on anesthetic success remains limited. Since no studies had directly examined dental anxiety's influence on the success of local anesthesia, particularly in teeth with acute painful irreversible pulpitis. Therefore, the aim of this study was to evaluate the effect of dental anxiety on the success of IANB in mandibular molars diagnosed with SIP, in patients with similar pain levels.We tested the following null hypothesis: Dental anxiety has no effect on IANB success during SIP treatment in mandibular molars.

## Materials and methods

### Study design and ethical approval

This prospective clinical study was approved by the Clinical Research Ethics Committee of Kutahya Health Sciences University (No: 2023-13/07). The study protocol was registered in the ClinicalTrials.gov database under the identifier NCT07124273. Participants were thoroughly informed about the study protocol, the potential risks and benefits, and the voluntary nature of participation. Written informed consent was obtained from all participants. The clinician performing the procedures was blinded to the patients' MDAS scores, and the participants were not informed of their anxiety classification.

### Sample size calculation

Sample size calculation was performed using GPower statistical software (version 3.1.9.7; Franz Faul, University of Kiel, Kiel, Germany). A two-tailed t-test was selected as the statistical test. The input parameters included an effect size (Cohen's d) of 0.5 (moderate), a Type I error rate ($\alpha$) of 0.05, and a desired power ($1-\beta$) of 0.94. Based on these values, the minimum required sample size was determined to be 52 participants, with 26 individuals in each group (low anxiety group: MDAS $\leq$10; moderate-to-high anxiety group: MDAS $\geq$11).

### Inclusion and exclusion criteria

A flow diagram illustrating patient recruitment, exclusion, and final analysis was constructed in accordance with the STROBE guidelines (Fig. 1). Individuals aged between 18 and 65 years, having no systemic diseases, no prior history of endodontic treatment, no internal or external root resorption or periapical lesions on radiographs, and having mandibular first molars with closed apices were included. All the included participants were diagnosed with SIP, had teeth that met Glickman's criteria for gingival health, periodontal pocket depths of less than 3 mm, and presented with moderate (visual analog scale (VAS): 4—6) or severe (VAS: 7—10) pain. The vitality of the teeth, which had not undergone previous endodontic treatment, was

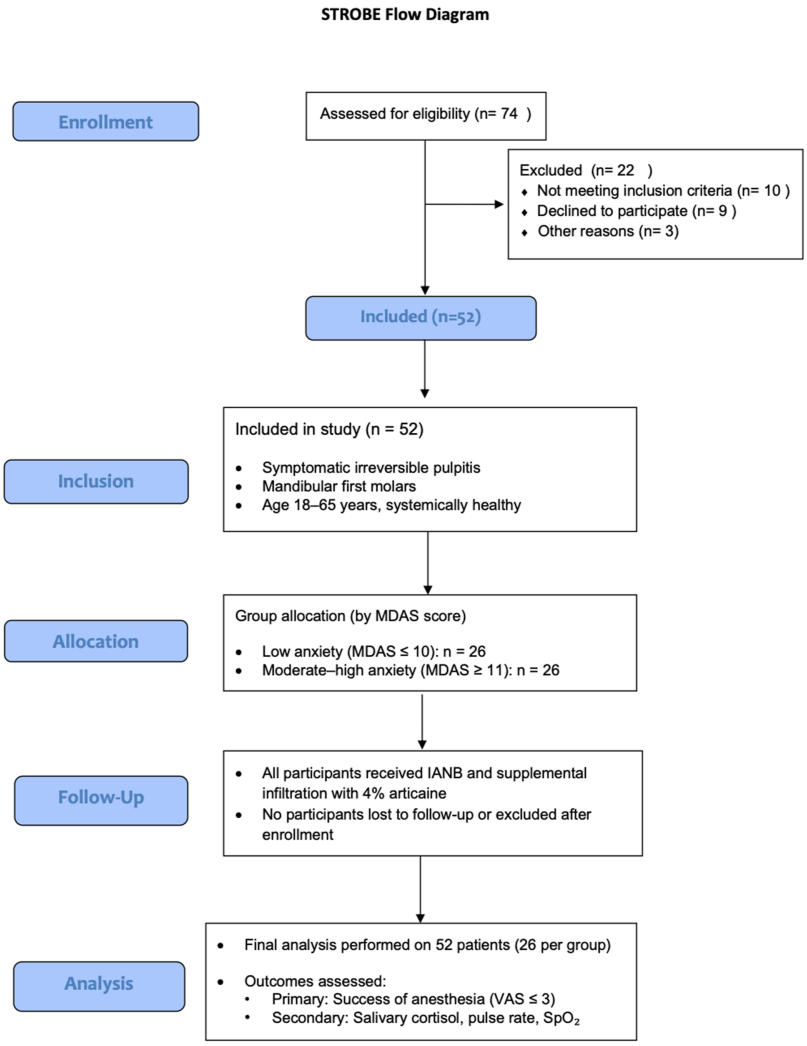


**Figure 1** Flow diagram of patient recruitment, exclusion, and analysis according to STROBE guidelines.

confirmed through electric pulp testing (EPT) and cold testing and was further verified by verifying the presence of bleeding upon accessing the pulp chamber.

Patients who had nonsteroidal anti-inflammatory drugs within 12 h before treatment, had a known allergy to articaine or epinephrine, had systemic or genetic diseases, had previously treated teeth, had teeth with extensive coronal destruction preventing rubber dam isolation, or had teeth with internal or external root resorption were excluded.

In total, 74 patients were initially evaluated. Nine declined to participate; four were excluded because their periodontal pocket depths exceeded 3 mm; six because of systemic health conditions; and three because of other reasons. Ultimately, 52 patients—27 female and 25 male—were included.

## Clinical procedure

To minimize the effects of circadian rhythm and fluctuations in cortisol levels, all treatments were performed between 09:00 and 12:00. On treatment day, the participants were allowed to rest in the clinic for 5 min, during which their demographic data were recorded and anxiety levels assessed using the MDAS. Those with MDAS scores $\leq$10 were classified as having low or no anxiety, those with scores between 11 and 18 as having moderate anxiety, and those with scores $\geq$19 as having dental phobia. Before anesthesia administration, the pulse rate and $SpO_2$ measurements were taken, and to determine the salivary cortisol levels, at least 2 mL of non-blood-contaminated saliva was collected using sterile, single-use collection tubes (Sali-Tubes 100; SLV-4158, DRG Instruments GmbH, Marburg, Germany) 15 min before anesthesia and after rinsing the mouth with water. They were immediately stored at −80 °C and transported to the central laboratory under cold-chain conditions. The salivary cortisol levels (ng/mL) were quantitatively measured using the enzyme-linked immunosorbent assay (ELISA) method with a Cortisol ELISA kit (DRG Instruments).

All procedures were performed by a single experienced endodontist with over 10 years of clinical experience, ensuring consistency in both anesthetic administration and

operative techniques. Intra-rater variability was minimized through adherence to a standardized clinical protocol. Before anesthetic injection, lidocaine spray (Locanest 10 % pump spray, Avixa, Istanbul, Turkey) was topically applied to the target area for 60 s using a cotton pellet. An IANB was then administered using a 27G needle with 1.8 mL of 4 % articaine hydrochloride with 1:100,000 epinephrine (Ultracaine DS Forte, Aventis, Istanbul, Turkey). Five minutes later, an additional 1.8 mL of articaine was administered via buccal-lingual infiltration in the same region. Lip numbness was assessed 15 min after the initial IANB, and patients who did not exhibit numbness were excluded. Following confirmation of lip anesthesia, access cavity preparation—considered the gold standard for evaluating pulpal anesthesia—was performed in all patients.

Following rubber dam isolation, the access cavities were prepared. Anesthesia was considered successful if the VAS score was between 0 and 3 during cavity preparation and unsuccessful if the score was 4 or higher. Supplemental anesthesia (either an intrapulpal or periodontal ligament injection) was administered to ensure comfortable continuation of treatment, and the type of supplemental anesthesia used was recorded for each patient.

### Statistical analysis

The normality of continuous variables was assessed using the Shapiro–Wilk test ($n < 50$) and Skewness–Kurtosis values. As the data showed normal distribution, parametric tests were applied. Descriptive statistics were presented as mean ± standard deviation, frequency (n), and percentage (%). Independent samples t-test was used for group comparisons, while binary logistic regression evaluated the effect of measurements on anesthetic success. Associations between categorical variables were examined with Chi-square and multiple correspondence analysis. Relationships between scale scores were assessed using Pearson correlation. A significance level of $\alpha = 0.05$ was adopted. All analyses were performed using IBM SPSS Statistics for Windows, version 26.0 (IBM Corp., Armonk, NY, USA).

## Results

This study was conducted in accordance with the STROBE guidelines, and a summary of the study is presented in the STROBE flow diagram (Fig. 1). In total, 52 patients—27 females (51.9 %) and 25 males (48.1 %), with a mean age of 38.23 ± 14.34 years—were included. Table 1 shows their descriptive characteristics and their distribution according to MDAS groups. Half of the participants ($n = 26$; 50 %) were assigned to the low anxiety group (MDAS ≤10), while the remaining 50 % ($n = 26$) were in the moderate-to-high anxiety group (MDAS ≥11). There were no statistically significant differences between the two groups in terms of age ($P = 0.400$), gender ($P = 0.406$), or baseline pain scores ($P = 0.335$). All patients exhibited profound lip anesthesia 15 min after IANB administration.

Anesthesia was successful in 19 patients (36.5 %), while 33 patients (63.5 %) needed additional anesthesia. The success rate of IANB anesthesia in the low anxiety group was 84.2 %, whereas it was only 15.8 % in the high anxiety group—this difference was statistically significant ($P < 0.001$; Table 1).

The high anxiety group had a significantly higher mean pulse rate (84.42 ± 9.42 bpm) than the low anxiety group ($P = 0.029$). Similarly, the high anxiety group had significantly higher salivary cortisol levels (1.08 ± 0.79 μg/dL) than the low anxiety group ($P = 0.001$; Table 1).

Comparisons based on anesthetic success revealed that the preoperative VAS score ($P = 0.023$), MDAS score ($P = 0.001$), mean pulse rate ($P = 0.034$), and salivary cortisol level ($P = 0.001$) were significantly higher in the anesthesia failure group (Table 2). The binary logistic regression analysis revealed salivary cortisol level as the only independent and statistically significant predictor of anesthetic failure (OR = 353.772; $P = 0.010$; Table 3).

In the correlation analysis, significant positive relationships were found between MDAS scores and both pulse rate ($r = 0.324$; $P = 0.019$) and cortisol levels ($r = 0.599$; $P = 0.001$) (Table 4). Multiple correspondence analysis revealed that the "Successful Anesthesia" category was located in the same region as the "MDAS ≤10" group, while

**Table 1** Participant characteristics and MDAS group distribution.

| Variable | Total (n = 52) (Mean ± SD/n, %) | MDAS ≤10 (n = 26) | MDAS ≥11 (n = 26) | p values |
|---|---|---|---|---|
| Age (years) | 38.23 ± 14.34 | 39.92 ± 14.88 | 36.54 ± 13.85 | 0.400 |
| Preoperative HP-VAS score | 8.73 ± 1.14 | 8.58 ± 1.17 | 8.88 ± 1.11 | 0.335 |
| Pulse rate (bpm) | 81.77 ± 8.86 | 79.12 ± 7.53 | 84.42 ± 9.42 | 0.029* |
| $SpO_2$ (%) | 97.35 ± 1.25 | 97.38 ± 1.55 | 97.31 ± 0.88 | 0.827 |
| Salivary cortisol (μg/dL) | 0.78 ± 0.66 | 0.49 ± 0.29 | 1.08 ± 0.79 | 0.001* |
| Gender, n (%) | Male: 25 (48.1 %) | Male: 11 (44.0 %) | Male: 14 (56.0 %) | 0.406 |
| | Female: 27 (51.9 %) | Female: 15 (55.6 %) | Female: 12 (44.4 %) | |
| Anesthetic success, n (%) | Success: 19 (36.5 %) | Success:16 (84.2 %) | Success: 3 (15.8 %) | 0.001* |
| | Failure: 33 (63.5 %) | Failure: 10 (30.3 %) | Failure: 23 (69.7 %) | |

HP-VAS = heaviest pain – visual analog scale; MDAS = modified dental anxiety scale; bpm = beats per minute; $SpO_2$ = peripheral oxygen saturation.
*P* values marked with * indicate statistical significance at $P = 0.05$.

**Table 2** Comparison of continuous variables according to anesthetic success.

| Variable | Successful Anesthesia (n = 19) (Mean ± SD) | Failed Anesthesia (n = 33) (Mean ± SD) | P values |
|---|---|---|---|
| Age (years) | 39.89 ± 16.84 | 37.27 ± 12.87 | 0.531 |
| Preoperative HP-VAS score | 8.26 ± 1.05 | 9.00 ± 1.12 | 0.023* |
| MDAS score | 9.89 ± 3.83 | 14.12 ± 4.31 | 0.001* |
| Pulse rate (bpm) | 78.37 ± 8.32 | 83.73 ± 8.68 | 0.034* |
| $SpO_2$ (%) | 97.26 ± 1.52 | 97.39 ± 1.09 | 0.720 |
| Salivary cortisol (μg/dL) | 0.36 ± 0.16 | 1.03 ± 0.71 | 0.001* |

HP-VAS = heaviest pain – visual analog scale; MDAS = modified dental anxiety scale; bpm = beats per minute; $SpO_2$ = peripheral oxygen saturation.
*P* values marked with * indicate statistical significance at $P = 0.05$.

the "Supplemental Anesthesia" category aligned with the "MDAS ≥11" group. This suggests that patients with low dental anxiety (MDAS ≤10) responded more favorably to anesthesia, and those with higher anxiety (MDAS ≥11) were more likely to require supplemental anesthesia.

## Discussion

Our study investigated dental anxiety's effect on the success of IANB in mandibular molars diagnosed with SIP. Patients with high dental anxiety exhibited significantly higher rates of IANB failure, salivary cortisol levels, and pulse rates than those with low anxiety. Cortisol concentration and anesthetic failure were also found to be strongly associated. The null hypothesis was thus rejected.

Compared to routine dental procedures, endodontic treatment is often perceived as more traumatic, particularly when effective pain control is not achieved. There is a significant correlation between preoperative pain and average MDAS scores before endodontic treatment.[15] Furthermore, those with endodontic treatment experiences have described the procedure as unpleasant and

**Table 3** Binary logistic regression analysis for predictors of anesthesia failure (n = 52).

| Predictor Variable | B | SE | P value | OR | 95 % CI for OR (Lower) | 95 % CI for OR (Upper) |
|---|---|---|---|---|---|---|
| Age | −0.020 | 0.030 | 0.497 | 0.980 | 0.925 | 1.039 |
| Preoperative HP-VAS score | 0.366 | 0.354 | 0.301 | 1.442 | 0.721 | 2.884 |
| MDAS score | 0.220 | 0.129 | 0.087 | 1.246 | 0.968 | 1.602 |
| Mean pulse (bpm) | 0.061 | 0.057 | 0.282 | 1.063 | 0.951 | 1.187 |
| Mean $SpO_2$ | −0.034 | 0.325 | 0.916 | 0.966 | 0.511 | 1.827 |
| Salivary cortisol (μg/dL) | 5.869 | 2.290 | 0.010* | 353.772 | 3.979 | 31457.004 |

**Model summary:** −2 log likelihood = 37.029, Cox & Snell $R^2 = 0.452$, Nagelkerke $R^2 = 0.618$.
Dependent variable = anesthesia outcome (1 = failure requiring supplemental anesthesia; 0 = successful anesthesia). Method = Enter.
HP-VAS = heaviest pain – visual analog scale; MDAS = modified dental anxiety scale; OR = odds ratio; CI = confidence interval.
*P* values marked with * indicate statistical significance at $P < 0.05$.

**Table 4** Pearson correlation analysis between continuous variables in the study population.

| Variable | Age | Preoperative HP-VAS score | MDAS score | Mean pulse (bpm) | $SpO_2$ | Salivary cortisol (μg/dL) |
|---|---|---|---|---|---|---|
| Age | 1 | | | | | |
| Preoperative HP-VAS score | r = 0.023<br>*P* = 0.871 | 1 | | | | |
| MDAS score | r = 0.025<br>*P* = 0.858 | r = 0.195<br>*P* = 0.166 | 1 | | | |
| Mean pulse (bpm) | r = −0.234<br>*P* = 0.095 | r = 0.310*<br>*P* = 0.025 | r = 0.324* 1<br>*P* = 0.019 | | | |
| Mean $SpO_2$ | r = −0.099<br>*P* = 0.487 | r = 0.094<br>*P* = 0.507 | r = −0.018<br>*P* = 0.897 | r = −0.069<br>*P* = 0.628 | 1 | |
| Salivary cortisol (μg/dL) | r = 0.009<br>*P* = 0.950 | r = 0.297*<br>*P* = 0.033 | r = 0.599*<br>*P* = 0.001 | r = 0.262<br>*P* = 0.060 | r = 0.093<br>P = 0.511 | 1 |

HP-VAS = heaviest pain – visual analog scale; MDAS = modified dental anxiety scale; bpm = beats per minute; $SpO_2$ = peripheral oxygen saturation; r = Pearson correlation coefficient; *P* = significance level.
*P* values marked with * indicate statistical significance at $P < 0.05$.

negative,[17] which may contribute to increased dental anxiety levels. To eliminate the confounding effect of prior endodontic experience and pain variability, we included only those with no endodontic treatment history and similar preoperative pain scores.

The choice of anesthetic formulation is an important factor that may influence the success of IANB, particularly in cases of SIP. Articaine, an amide-type local anesthetic, is widely used in dental practice due to its favorable pharmacokinetic profile and enhanced hard tissue diffusion attributed to its thiophene ring structure.[18] Several investigations have compared the anesthetic efficacy of articaine with other local anesthetic agents, and most studies have reported no significant difference between articaine and lidocaine when used for IANB injections.[19–21] However, some reports suggest that articaine may offer certain advantages over lidocaine, including a faster onset and longer duration of pulpal anesthesia under specific clinical conditions.[22] Based on this evidence, 4 % articaine with 1:100,000 epinephrine was selected in the present study to achieve reliable anesthesia with adequate onset time and duration. In cases of SIP, the use of supplemental anesthetic techniques has been recommended to reduce the risk of IANB failure.[14] Zanjir et al.[23] reported that, instead of administering only IANB, supplementing it with buccal and lingual infiltrations using 4 % articaine significantly enhanced anesthetic success in SIP cases. We also employed an additional buccal and lingual infiltration of 1.8 mL 4 % articaine 5 min after the standard IANB procedure. Furthermore, the standardization of the IANB protocol by having all injections performed by a single clinician minimized methodological variability related to anesthetic administration. Future studies comparing different anesthetic agents under standardized clinical conditions may provide deeper insight into the influence of anesthetic formulation on IANB success.

Cold test and EPT are commonly used to assess pulpal anesthesia, but their reliability may be limited in SIP,[24,25] especially as partial anesthesia can block A-fiber responses while deeper C-fiber regions remain responsive.[26] Therefore, access cavity preparation was used as the gold standard, and lip numbness only as an inclusion criterion.

Dental anxiety's prevalence varies depending on clinical conditions and patient population. Tellez et al.[27] assessed dental anxiety among patients seeking dental care, and only about half of them (49.2 %) reported moderate to high anxiety levels. Similarly, two other studies reported rates of 54.8 % and 58.8 %, respectively,[8,28] but they included routine dental check-up patients and those requiring emergency dental care in their analyses. In contrast, Dou et al.[15] reported a much higher prevalence of moderate to high dental anxiety (83.1 %) among patients who sought urgent dental treatment and reported moderate-to-severe pain. This elevated rate, the authors suggested, could be attributed to the association between preoperative pain and anxiety, emphasizing a significant correlation between pre-treatment pain intensity and average MDAS scores. In our study, patients with SIP were stratified into two equal groups based on their preoperative MDAS scores, and we thus evaluated dental anxiety's impact on anesthetic success in individuals experiencing similar pain levels. This relationship was assessed in conjunction with physiological parameters such as salivary cortisol, oxygen saturation, and pulse rate. Our findings revealed a statistically significant association between high dental anxiety levels and anesthetic failure. Specifically, 69.7 % of patients with high anxiety required additional anesthesia, compared to only 30.3 % in the low anxiety group. This association was further supported by the objective physiological indicators of stress. Those with high anxiety exhibited significantly elevated mean pulse rates and salivary cortisol levels than those with lower anxiety.

Salivary cortisol, secreted by the HPA axis, is widely accepted in stress research as a valid, reliable, and non-invasive biomarker of psychological stress.[29,30] Numerous studies have explored the relationship between dental anxiety and salivary cortisol concentrations.[31,32] Moreover, it has been reported that dental anxiety increases salivary cortisol levels and affects the average pulse rate.[33] The patients in our study who required supplemental anesthesia exhibited significantly higher MDAS scores, mean pulse rates, and salivary cortisol levels than those who had successful anesthesia. Among these factors, logistic regression analysis identified salivary cortisol level as the strongest and only independent predictor of anesthetic failure. This suggests that the acute stress response triggered by dental anxiety may directly impair the effectiveness of local anesthesia through cortisol-mediated mechanisms. Cortisol may thus serve as an objective biological indicator of anxiety as well as a clinically valuable predictor of local anesthetic success.

In this study, several standardization measures were implemented to minimize the influence of potential confounding factors. To reduce gender-related variability in cortisol response, a comparable number of female ($n = 27$) and male ($n = 25$) participants were included. To minimize circadian fluctuations in cortisol levels and patient fatigue, all clinical procedures were performed between 09:00 and 12:00 a.m., and each participant was allowed a 5-min rest period before treatment. In addition, operator-related variability was reduced by having all injections administered by a single experienced and calibrated clinician using a standardized IANB protocol. These procedures ensured methodological standardization and allowed the study to be conducted in a controlled clinical setting.

Our study has limitations. Its relatively small sample size may limit the findings' generalizability, and its evaluation was limited to the IANB technique in mandibular molar teeth, restricting the findings' applicability to other tooth groups and anesthetic techniques. Although the use of a single calibrated operator reduced inter-operator variability and ensured standardization, it may also have introduced operator-dependent bias, potentially limiting the external validity of the findings. Therefore, future studies with larger sample sizes and multi-center designs involving multiple calibrated clinicians are recommended to improve the generalizability and reliability of the results. Investigating dental anxiety's impact on various anesthetic techniques can also unveil valuable insights into clinical practice. Furthermore, evaluating the potential effects of anxiety-reducing interventions[34,35] (e.g., music, aromatherapy, behavioral approaches, etc.) on the success of local anesthesia could offer meaningful contributions to the literature and clinical protocols.

Dental anxiety significantly affects the success of local anesthesia in SIP patients with similar preoperative pain levels. Positive correlations between high MDAS scores, increased salivary cortisol, and elevated pulse suggest anxiety may impair IANB efficacy via physiological stress responses. Assessing anxiety before treatment and applying appropriate management strategies are essential for improving patient comfort and treatment success. Salivary cortisol may also serve as an objective, biological marker with potential clinical utility in predicting anesthetic failure.

## Declaration of competing interest

The authors have no conflicts of interest relevant to this article.

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