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Aromatherapy and anxiety in a dental waiting room: an *N*-of-1 crossover study

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ABSTRACT

Introduction: Dental fear and anxiety are highly prevalent conditions that negatively affect participant attendance, cooperation and clinical outcomes. Non-pharmacological interventions, such as aromatherapy, have been proposed as adjunctive strategies to reduce anxiety in dental settings.
Objectives: To evaluate the effect of lavender (*Lavandula angustifolia*) essential oil inhalation on dental anxiety and physiological parameters in a clinical context.
Methodology: A single-subject (N-of-1) crossover study (ABBA design) was conducted. One participant attended four clinical sessions under alternating lavender (2%) and placebo conditions. Anxiety levels were assessed using the State-Trait Anxiety Inventory (STAI-Y1 and STAI-Y2) and the Modified Dental Anxiety Scale. Physiological parameters, including blood pressure, heart rate and oxygen saturation, were recorded before and after each session. Data were analyzed descriptively.
Results: A reduction in state anxiety (STAI-Y1) was observed across all sessions, regardless of condition, with consistent decreases in scores, while the Modified Dental Anxiety Scale scores showed variable changes and were interpreted as exploratory. Physiological parameters demonstrated no consistent or clinically relevant differences between conditions.
Conclusion: Lavender aromatherapy may contribute to reduced perceived dental anxiety; however, similar improvements observed under placebo conditions suggest a relevant contextual or placebo effect. These findings highlight the need for further controlled studies to clarify the specific clinical effectiveness of aromatherapy in dental practice.

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RESUMO

Introdução: O medo e a ansiedade dentária são condições altamente prevalentes que comprometem a assiduidade, a cooperação do paciente e os resultados clínicos. Intervenções não farmacológicas, como a aromaterapia, têm sido propostas como estratégias adjuvantes na redução da ansiedade em contexto de medicina dentária.
Objetivos: Avaliar o efeito da inalação de óleo essencial de lavanda (*Lavandula angustifolia*) na ansiedade dentária e em parâmetros fisiológicos em contexto clínico.
Metodologia: Foi conduzido um estudo de caso único (N-of-1) com desenho cruzado (tipo ABBA). Um participante foi submetido a quatro sessões clínicas sob condições alternadas de lavanda (2%) e placebo. A ansiedade foi avaliada através do *State-Trait Anxiety Inventory* (STAI-Y1 e STAI-Y2) e da *Modified Dental Anxiety Scale*. Os parâmetros fisiológicos (pressão arterial, frequência cardíaca e saturação de oxigénio) foram registados antes e após cada sessão. Os dados foram analisados de forma descritiva.
Resultados: Observou-se uma redução da ansiedade de estado (STAI-Y1) em todas as sessões, independentemente da condição. As medidas do STAI-Y1 evidenciaram uma diminuição consistente, enquanto a *Modified Dental Anxiety Scale* apresentou variabilidade e foi interpretada de forma exploratória. Os parâmetros fisiológicos não demonstraram diferenças consistentes ou clinicamente relevantes entre as condições.
Conclusões: A aromaterapia com lavanda poderá contribuir para a redução da ansiedade dentária percebida; contudo, a melhoria observada também na condição placebo sugere um efeito contextual relevante. Estes resultados reforçam a necessidade de estudos controlados, com maior dimensão amostral, para clarificar a eficácia clínica específica da aromaterapia em medicina dentária.

Introduction

Dental fear and anxiety (DFA) are highly prevalent conditions that significantly affect participant attendance, cooperation and clinical oral health outcomes.[1] Individuals with elevated anxiety levels are more likely to avoid dental care, resulting in disease progression, delayed diagnosis and the need for more complex and invasive treatments.[2] In addition, DFA can negatively influence participant behaviour during clinical procedures, compromising treatment efficiency and increasing clinical difficulty.[3]

Several strategies have been proposed to manage dental anxiety, including pharmacological approaches such as sedation and anxiolytic medication, as well as behavioural techniques.[4] Although pharmacological methods can be effective, they may be associated with adverse effects, increased costs and the need for additional clinical resources.[5] As a result, non-pharmacological interventions have gained increasing attention due to their favourable safety profile, accessibility and ease of implementation in routine clinical practice.[6]

Aromatherapy has emerged as a complementary therapeutic approach aimed at reducing anxiety through the use of essential oils.[7] Lavender (*Lavandula angustifolia*) is one of the most extensively studied essential oils and has been associated with anxiolytic, sedative and effects on autonomic regulation .[8,9] The proposed mechanism of action involves interaction with the limbic system and modulation of neurotransmitter activity, particularly gamma-aminobutyric acid (GABA), which may lead to decreased sympathetic activity and improved emotional regulation.[10,11]

Despite these proposed mechanisms, evidence regarding the effectiveness of lavender aromatherapy in dental settings remains inconsistent.[12] While some studies report reductions in anxiety levels, others suggest that observed improvements may be influenced by contextual factors, including environmental conditions, participant expectations and placebo effects.[13]

Given the lack of consensus in the literature and the clinical relevance of non-pharmacological strategies, further investigation is warranted.

This study aimed to evaluate the effect of lavender essential oil inhalation on dental anxiety and physiological parameters in a clinical setting.

Methodology

Study design and participant selection

This study was designed as a single-subject (N-of-1) crossover study, conducted in the pre-operative waiting room of the Dental Pedagogical Clinic of University Fernando Pessoa (CPMD-UFP).

One adult participant with self-reported and clinically observed dental anxiety was included in the study. The participant was a 47-year-old female attending the dental clinic for the placement of a lower dental prosthesis. The

participant was selected based on clinically significant dental anxiety identified during the initial consultation. During the first visit, the participant presented observable signs of anxiety and explicitly reported a high level of fear related to dental treatment. The participant reported a long-standing history of dental and general medical anxiety without a formal diagnosis of dental phobia had been established. Medical history was non-contributory, with no relevant systemic conditions or respiratory disorders. The participant reported no known allergies to essential oils and no previous experience with aromatherapy interventions. The participant was fully informed about the objectives and procedures and provided written informed consent prior to inclusion. Confidentiality was ensured, and the participant retained the right to withdraw at any point without any consequences.

Inclusion criteria were defined as follows: adult (≥18 years), absence of unstable respiratory conditions and absence of clinically significant anosmia or hyposmia. Exclusion criteria included hypersensitivity to fragrances or essential oils, uncontrolled asthma, pregnancy, odor-triggered migraine, acute rhinitis, and any neurological or systemic condition that could interfere with olfactory perception or physiological responses.

All experimental sessions were conducted under standardized environmental conditions, including controlled ventilation, stable ambient temperature, consistent lighting, and minimal external noise. These measures were implemented to minimize environmental variability and minimize potential confounding factors that could influence anxiety levels or physiological responses.

Materials and instruments

The intervention consisted of 4 mL of Lavandula angustifolia essential oil (Pranarôm, Spain) added to 200 mL of distilled water in the ultrasonic diffuser reservoir, corresponding to a nominal 2% (v/v) preparation. As essential oils are not fully water-soluble, this preparation should be interpreted as a diffuser reservoir mixture rather than a true aqueous solution. The mixture was freshly prepared approximately 15 minutes before the participant's arrival. Aromatherapy was administered through inhalation using an ultrasonic diffuser (≥200 mL capacity) positioned close to the participant in a dental waiting room of approximately 18–20 m^2. The diffuser operated continuously for 20 minutes during the waiting period prior to the dental procedure. The concentration and delivery method were selected based on previous literature suggesting effectiveness and safety in clinical environments[15]. The placebo condition consisted of distilled water alone, delivered using the same device and under identical environmental conditions.

Physiological parameters were assessed using validated and calibrated equipment. Blood pressure and heart rate were measured using a validated automatic sphygmomanometer (A&D Medical), while peripheral oxygen saturation (SpO_2) was assessed using a pulse oximeter (Viatom). All measurements were obtained following standardized procedures, with the participant in a seated and resting position. A single blood pressure and heart rate measurement was recorded at each assessment timepoint (T0 and T1); repeated readings were not obtained or averaged.

Psychological assessment included validated instruments for the Portuguese population [32,33,34]. The State-Trait Anxiety Inventory (STAI-Y1 and STAI-Y2) [32] was used to assess both state and trait anxiety, each comprising 20 items scored on a 4-point Likert scale. Higher scores indicate greater anxiety levels. The Modified Dental Anxiety Scale (MDAS) [33] was used to assess dental-specific anxiety and consists of five items scored from 1 to 5, with ranging from 5 to 25. Higher scores indicate greater anxiety, and established thresholds allow classification of high dental anxiety.

Additionally, an exploratory subjective satisfaction questionnaire consisting of five Likert-scale items (1–5), developed by the author, was administered to evaluate perceived relaxation, olfactory pleasantness, and acceptance of aromatherapy as a potential adjunctive strategy in dental care. This instrument was not formally validated and was used for descriptive purposes only

Study procedure

The participant attended four clinical sessions scheduled under similar conditions, including comparable appointment times, waiting periods, and clinical context, in order to reduce temporal and situational variability. The sessions were conducted under two experimental conditions: lavender exposure (intervention A) and placebo (condition B), following a ABBA sequence to balance order effects and reduce potential carryover effects. Sessions were scheduled at one-week intervals. Dental procedures were considered broadly comparable in expected stress level and clinical complexity, with each appointment lasting approximately 1 hour and 15 minutes. The participant was assessed after a standardized acclimatization period of 5 minutes following arrival at the clinic.

At the beginning of each session, baseline measurements (T0) were recorded immediately upon arrival, prior to exposure, in the waiting room. These included physiological parameters (systolic and diastolic blood pressure, heart rate, and oxygen saturation) and psychological assessments (STAI-Y1, STAI-Y2, and MDAS).

Following baseline assessment, the participant remained seated in the waiting room and was exposed to the assigned condition for approximately 20 minutes, with the diffuser positioned at a standardized distance from the participant. The diffuser operated continuously during this period,

ensuring consistent and consistent dispersion of the volatile compounds in the ambient air.

After the exposure period, all measurements were repeated (T1) under identical conditions. The same investigator conducted all assessments to ensure procedural consistency and minimize inter-observer variability.

At the end of each session, the participant completed the satisfaction questionnaire, providing qualitative insight into subjective perception of the intervention. No adverse events were observed or reported, and all sessions were completed without interruption.

Data analysis

Given the single-subject (N-of-1) design, data were analyzed descriptively. Variations in physiological and psychological variables were calculated as the difference between post-intervention (T1) and baseline (T0) values for each session.

Changes in systolic and diastolic blood pressure, heart rate, and oxygen saturation were analyzed alongside changes in STAI-Y1, STAI-Y2, and MDAS scores. These variations were examined across lavender and placebo conditions to explore potential differences associated with the intervention.

Results were summarized and presented in tabular form to facilitate interpretation and comparison between sessions and conditions. Particular attention was given to identifying consistent patterns across sessions rather than isolated variations, acknowledging the exploratory nature of the design.

Although STAI-Y2 and MDAS are not specifically designed to detect short-term intra-session changes, both instruments were included to explore potential variations in perceived anxiety across repeated exposures. STAI-Y2 was considered mainly as a measure of baseline and session-related emotional adaptation, while MDAS was interpreted as an indicator of dental anxiety perception rather than an immediate outcome measure. Therefore, changes observed between T0 and T1 for these instruments were treated as exploratory and interpreted with caution.

Ethical considerations

The study adhered to the ethical principles outlined in the Declaration of Helsinki. Written informed consent was obtained prior to participant participation, and all procedures ensured participant safety, confidentiality, and data protection. The study protocol was approved by The Ethics committee of University Fernando Pessoa (Approval No. FCS/MMED – 789/25).

Results

Physiological parameters and anxiety levels were assessed across four clinical sessions following an ABBA design, in which condition A corresponded to. *Lavandula angustifolia* essential oil exposure and condition B to placebo. In each session, values were recorded before exposure (T0) and after approximately 20 minutes (T1).

Regarding hemodynamic parameters (Table 1), variations between T0 and T1 were observed across sessions. In the first lavender session, systolic blood pressure (Table 2) decreased from 108 to 99 mmHg, while diastolic pressure slightly increased. During placebo sessions, inconsistent variations were observed. In the fourth session, again under lavender exposure, a slight increase in systolic blood pressure was recorded.

Table 1. Variation (Δ) in hemodynamic parameters between baseline (T0) and post-intervention (T1).

Session	Condition	ΔSBP	ΔDBP	ΔHR
1	Lavender	-9	+5	+9
2	Placebo	+6	-13	-6
3	Placebo	-1	+5	0
4	Lavender	+2	+7	-5

Legend: SBP = systolic blood pressure (mmHg); DBP = diastolic blood pressure (mmHg); HR = heart rate (beats per minute).

Table 2. Blood pressure values (Baseline (T0) versus post-intervention (T1).

Session	Condition	SBP T0	SBP T1	DBP T0	DBP T1
1	Lavender	108	99	66	71
2	Placebo	115	121	94	81
3	Placebo	109	108	73	78
4	Lavender	109	111	70	77

Legend: SBP = systolic blood pressure (mmHg); DBP = diastolic blood pressure (mmHg); T0 = baseline measurement; T1 = post-intervention measurement.

Heart rate (Table 3) showed variations across sessions, with an increase in the first session (+9 bpm), a decrease in the second (−6 bpm), stability in the third session, and a decrease in the fourth session (−5 bpm). These variations did not follow a consistent pattern between lavender and placebo conditions. Peripheral oxygen saturation (Table 3) remained stable throughout all sessions, ranging between 98% and 99%, suggesting no relevant physiological impact of either condition on oxygenation status.

Table 3. Heart rate and oxygen saturation (T0 vs T1).

Session	Condition	HR T0	HR T1	SpO2 T0	SpO2 T1
1	Lavender	67	76	98	99
2	Placebo	69	63	98	98
3	Placebo	64	64	98	99
4	Lavender	58	53	98	99

Legend: HR = heart rate (beats per minute); SpO_2 = peripheral oxygen saturation (%); T0 = baseline measurement; T1 = post-intervention measurement.

Anxiety levels were assessed using the STAI and MDAS instruments (Table 4). A consistent reduction in STAI-Y1 (state anxiety) scores was observed across all sessions following the waiting period, regardless of the condition

applied. This reduction ranged from 7 to 9 points, indicating a generalized decrease in perceived anxiety during the pre-operative phase.

For STAI-Y2 (trait anxiety), variations were observed across sessions, with reductions ranging from 2 to 7 points in three sessions and stability in the final session. Given that STAI-Y2 is designed to assess relatively stable aspects of anxiety, these changes are not interpreted as immediate effects of the intervention but rather as exploratory observations that may reflect progressive familiarization with the clinical environment or contextual adaptation over repeated sessions.

Dental anxiety assessed through MDAS demonstrated variability across sessions. While minimal changes were observed in the initial sessions, larger reductions were recorded in later sessions. Considering that MDAS is primarily validated as a pre-procedural measure rather than a tool for detecting immediate intra-session changes, these results should be interpreted cautiously. The observed reductions may reflect a combination of contextual factors, increased familiarity with the clinical setting, and repeated exposure, rather than a direct effect of the intervention alone.

Table 4. Anxiety scores (T0 vs T1).

Session	Condition	STAI-Y1 T0	STAI-Y1 T1	STAI-Y2 T0	STAI-Y2 T1	MDAS T0	MDAS T1
1	Lavender	31	22	30	23	18	19
2	Placebo	29	21	32	30	18	17
3	Placebo	33	26	34	28	21	11
4	Lavender	30	23	31	31	21	14

Legend: STAI-Y1 = State-Trait Anxiety Inventory (state anxiety); STAI-Y2 = State-Trait Anxiety Inventory (trait anxiety); MDAS = Modified Dental Anxiety Scale; T0 = baseline measurement; T1 = post-intervention measurement. Higher scores indicate higher levels of anxiety.

The participant reported high satisfaction scores reflecting perceived relaxation and acceptance of the intervention, with values ranging from 4.0 to 5.0 across all sessions (Table 5).

Table 5. Participant Satisfaction Scores (Likert Scale 1–5).

Session	Satisfaction Score
1	4,8
2	5
3	4
4	4,2

Discussion

Dental fear and anxiety (DFA) remain major challenges in dental practice, substantially affecting participant adherence, cooperation, and clinical outcomes.[14,15] As described by Steenen et al., participants with dental anxiety frequently postpone or avoid treatment, contributing to disease progression and increased treatment complexity.[16] This general background is consistent with the rationale of the present study, which aimed to explore whether a simple environmental intervention, namely lavender aromatherapy, could reduce anxiety in a real pre-operative dental setting.

In the present study, the most consistent finding was a reduction in state anxiety, as measured by State-Trait Anxiety Inventory (STAI-Y1), across all four sessions. The decreases ranged from −7 to −9 points, suggesting a relevant short-term reduction in perceived anxiety after the waiting period. These findings are broadly in line with previous studies reporting reductions in anxiety scores following lavender exposure in dental environments. Venkataramana et al. observed significantly lower anxiety levels in participants exposed to lavender fragrance in a dental clinic, while Nardarajah et al. also reported lower anxiety levels in participants undergoing mandibular third molar extraction after exposure to lavender aroma.[14,17] Similarly, Premkumar et al., in their review, concluded that essential oils—particularly lavender—are frequently associated with improved subjective anxiety outcomes before dental treatment.[19] These comparisons support the hypothesis that aromatherapy may contribute to reducing anticipatory anxiety in dental settings.

However, an important aspect of our results is that reductions in STAI-Y1 were not exclusive to lavender sessions. Similar reductions were also found during placebo exposure, introducing a critical interpretative dimension. This differs from studies in which lavender demonstrated clearer superiority over control conditions, such as those described by Venkataramana et al.[14] On the other hand, our results more consistent with the observations of Bozkurt and Vural, who reported that in more stressful clinical settings, the anxiolytic effect of aromatherapy may be attenuated, with no clear difference compared to placebo.[28] Mousavi et al. also described the importance of contextual and procedural factors in influencing the magnitude of the response to aromatherapy.[26] Therefore, our findings do not contradict the literature but rather place this case within the subgroup of studies suggesting that the effects of aromatherapy may be partly, and sometimes substantially, influenced by non-specific factors. In particular, a central role may be attributed to the development of trust and rapport between clinician and participant, which is known to modulate anxiety perception and pain anticipation in dental settings. Continuous interpersonal interaction, empathetic communication, and the clinician's ability to provide reassurance and clear procedural explanations may have contributed to reducing anticipatory anxiety independently of the aromatherapeutic intervention. Furthermore, the progressive exposure to clinical procedures, from initial impressions to subsequent verification stages, may have facilitated habituation and increased procedural familiarity, thereby lowering uncertainty and perceived

threat. This gradual desensitization process, combined with repeated reassurance and the establishment of a predictable clinical environment, may have significantly attenuated anxiety levels, making it difficult to isolate the specific effect of aromatherapy from these contextual and relational factors.

This point is particularly relevant when considering placebo and environmental effects. In our study, the waiting room environment was controlled, quiet, and standardized, and the participant was aware of being observed and followed during the intervention. Such contextual elements may themselves reduce anxiety. This interpretation is supported by Benedetti and by Colloca and Miller, who emphasized that placebo effects are especially relevant in subjective outcomes such as anxiety and pain perception.[24,25] Thus, compared with studies reportingstronger intervention-specific effects, our findings suggest that part of the observed benefit may derive from the therapeutic context rather than exclusively from the lavender essential oil itself.

Trait anxiety, as measured by STAI-Y2, also showed reductions in three of the four sessions, ranging from −2 to −7 points, with stability in the last session. Although STAI-Y2 is traditionally considered more stable than STAI-Y1, short-term changes can still occur in repeated assessments in emotionally loaded contexts. In our study, the reduction in STAI-Y2 is compatible with a general perception of emotional relief over repeated exposure to the dental setting. This is indirectly in agreement with studies suggesting that repeated contact with a controlled and reassuring clinical environment may reduce subjective distress, even when the intervention is not purely pharmacological.[24,30] Compared with studies that emphasize only immediate state-anxiety reduction, our data may suggest that repeated sessions in a calm environment, with or without lavender, can contribute to broader emotional adaptation.

The MDAS results add another relevant layer to the interpretation. Unlike STAI-Y1, which decreased consistently in all sessions, MDAS scores showed greater variability. Minimal changes were seen in the early sessions, whereas later sessions demonstrated marked reductions, including −10 points in the third session and −7 points in the fourth. These reductions are clinically relevant, particularly because MDAS scores above 19 are generally considered indicative of high dental anxiety. In this context,the participant shifted from a high-anxiety range to a substantially lower score in some sessions. These findings are partly consistent with Venkataramana et al., who also reported reductions in dental anxiety measured by the MDAS.[14] However, in the present study, the most pronounced reductions were observed not immediately and not exclusively under lavender exposure. This pattern suggests that habituation to the clinical setting, increased procedural familiarity, or repeated participation in the study may have influenced the later results. This interpretation is supported by the work of Matos et al., who emphasized that olfactory and emotional responses are strongly modulated by individual and contextual experience.[30]

With regard to physiological parameters, our results provide limited support of a specific anxiolytic effect. Systolic blood pressure ranged from −9 mmHg to +6 mmHg, and heart rate ranged from −6 to +9 bpm across sessions, without a consistent pattern distinguishing lavender from placebo. These findings are particularly important as they allow comparison with authors who described more evident physiological effects. Alkanan et al. reported that aromatherapy may positively influence hemodynamic parameters in anxious dental participants, and Premkumar et al. also discussed stabilization of cardiovascular responses in some studies.[15,19] In contrast, our results are more aligned with studies showing variable or non-significant physiological changes.[28,26] This suggests that while subjective anxiety may improve, objective autonomic responses may be less sensitive, more variable, or dependent on additional factors such as baseline stress level, type of procedure, and individual reactivity.

The lack of a consistent cardiovascular response in our study may be explained by several factors. First, the participant was exposed in a waiting-room context rather than during a highly invasive or painful procedure. Second, the study involved only a single participant, so normal physiological variability may account for a substantial proportion of the observed changes. Third, the participant may have had relatively low hemodynamic reactivity despite reporting subjective anxiety. This interpretation is consistent with the heterogeneous physiological findings reported by other authors and suggests that subjective and physiological markers of anxiety do not always evolve in parallel. [28–19]

Oxygen saturation remained stable between 98% and 99% in all sessions. This finding does not provide evidence of anxiolytic efficacy per se but supports the safety of the intervention. This is consistent with previous literature describing aromatherapy as a safe adjunctive strategy in dental and healthcare settings, with minimal adverse effects when used appropriately.[29] From a clinical perspective, this is important because it supports the use of aromatherapy as a low-risk complementary measure.

Another relevant point comparing with the literature is the possible indirect action of aromatherapy through environmental modification. Herz described the strong relationship between olfaction and emotion, while Mousavi et al. highlighted that pleasant aromas may reduce the impact of unpleasant clinical odors commonly associated with fear.[26,31] Our findings are compatible with this interpretation. Even if lavender did not clearly outperform placebo across all outcomes, the intervention may still have improved the participant's subjective experience by

contributing to a calmer and more acceptable sensory environment.

Taken together, the present study suggests that lavender aromatherapy may contribute to reduced perceived anxiety, but its effects are not easily separated from placebo and contextual influences. Compared with studies reporting clear superiority of lavender over control conditions, our results are more cautious and support the view that aromatherapy should be interpreted as part of a broader therapeutic environment rather than as an isolated anxiolytic tool.[14,17,28] This should not be considered a limitation of the study alone but rather a reflection of the complexity of anxiety modulation in clinical settings.

From a methodological perspective, the N-of-1 crossover design is a strength because it allows intra-individual comparison and highlights how one participant responds across repeated conditions. At the same time, it limits generalizability. Therefore, while our findings are useful for generating clinical hypotheses, they should not be generalized without caution. An important methodological consideration concerns the use of STAI-Y2 and MDAS for intra-session comparisons. STAI-Y2 is traditionally used to assess trait anxiety, and MDAS is primarily designed as a pre-procedural measure of dental anxiety. Therefore, their sensitivity to short-term changes within a single session is limited. The variations observed in these measures in the present study should be interpreted as exploratory and may reflect contextual adaptation, repeated exposure, or measurement variability rather than direct effects of the intervention. Future studies should compare lavender and placebo in larger randomized samples, ideally with standardized waiting-room exposure, procedure type, and additional biomarkers such as salivary cortisol. This would allow a more precise comparison with the existing literature and help clarify whether the benefit of aromatherapy is primarily pharmacological, contextual, or both.

Limitations

This study presents several limitations that should be considered when interpreting the findings. First, the single-subject (N-of-1) design limits generalizability and precludes statistical inference beyond exploratory observations. Second, the limited number of sessions increases susceptibility to order effects and habituation, particularly in a repeated-measures design. Third, the use of State-Trait Anxiety Inventory (STAI-Y2) and Modified Dental Anxiety Scale (MDAS) to assess intra-session changes represents a methodological limitation, as these instruments are not primarily designed for short-term repeated assessment. Furthermore, blood pressure and heart rate were assessed using a single measurement at each timepoint, without repeated readings or averaging, which may have reduced the reliability of the physiological measurements. Moreover, the placebo condition (distilled water) may not have ensured complete blinding, given the perceptible difference between scented and non-scented conditions. No formal blinding procedures or manipulation checks (e.g., condition guessing, scent intensity or pleasantness ratings) were implemented. Although not systematically assessed, the participant spontaneously reported perceiving a pleasant scent, despite the diffuser containing only distilled water, suggesting that expectancy and contextual factors may have influenced the observed reductions in anxiety.

Furthermore, potential confounding factors such as caffeine intake, sleep quality, menstrual cycle phase, and recent acute stressors were not systematically recorded or controlled. These variables may have influenced both subjective anxiety and physiological responses. Finally, the limited number of sessions and the predefined ABBA sequence may have amplified the effect of familiarization with the clinical environment, suggesting that the observed reduction in anxiety could be largely influenced by progressive adaptation rather than the intervention itself.

Future studies should consider including brief state-sensitive instruments, such as the STAI-6 or visual analogue anxiety scales (VAS-A), to improve the assessment of short-term anxiety changes.

Conclusion

Within the limitations of this single-subject crossover study, exposure to lavender aromatherapy was associated with a consistent reduction in perceived state anxiety across sessions. However, similar reductions observed under placebo conditions suggest that contextual and non-specific effects, including environmental conditions and repeated exposure to the clinical setting, may play a substantial role in anxiety modulation.

These findings indicate that while aromatherapy may contribute to improving the participant's subjective experience, its specific anxiolytic effect remains difficult to isolate in this context. From a clinical perspective, simple environmental interventions - whether olfactory or contextual - may still be valuable as part of a broader strategy to reduce preoperative anxiety and improve participant comfort.

Further studies with larger samples, improved blinding strategies, and outcome measures specifically designed to capture short-term anxiety changes are required to clarify the specific contribution of aromatherapy in dental practice. Future research should also consider randomized alternating-treatment designs and active odor control conditions involving pleasant non-lavender scents matched for perceived intensity and pleasantness, in order to better distinguish lavender-specific effects from general olfactory stimulation, expectancy, and contextual influences. In addition, objective autonomic biomarkers such as heart rate variability (HRV) and electrodermal activity

should be included to strengthen physiological assessment and causal interpretation.

Data availability statement: The data supporting the findings of this study are available from the corresponding author upon reasonable request.

References

1. Armfield JM, Slade GD, Spencer AJ. Dental fear and adult oral health in Australia. Community Dent Oral Epidemiol. 2009 Jun;37(3):220-30. doi: 10.1111/j.1600-0528.2009.00468.x. PMID: 19508270.
2. Hill KB, Chadwick B, Freeman R, O'Sullivan I, Murray JJ. Adult Dental Health Survey 2009: relationships between dental attendance patterns, oral health behaviour and the current barriers to dental care. Br Dent J. 2013 Jan;214(1):25-32. doi: 10.1038/sj.bdj.2012.1176. PMID: 23306496.
3. Locker D. Psychosocial consequences of dental fear and anxiety. Community Dent Oral Epidemiol. 2003 Apr;31(2):144-51. doi: 10.1034/j.1600-0528.2003.00028.x. PMID: 12641596.
4. Appukuttan DP. Strategies to manage participants with dental anxiety and dental phobia: literature review. Clin Cosmet Investig Dent. 2016 Mar 10;8:35-50. doi: 10.2147/CCIDE.S63626. PMID: 27022303; PMCID: PMC4790493.
5. Coulthard P. Conscious sedation guidance. Evid Based Dent. 2006;7(4):90-1. doi: 10.1038/sj.ebd.6400441. PMID: 17187034.
6. Newton JT, Asimakopoulou K. Minimally invasive dentistry: Enhancing oral health related behaviour through behaviour change techniques. Br Dent J. 2017 Aug 11;223(3):147-150. doi: 10.1038/sj.bdj.2017.659. PMID: 28798465.
7. Perry R, Terry R, Watson LK, Ernst E. Is lavender an anxiolytic drug? A systematic review of randomised clinical trials. Phytomedicine. 2012 Jun 15;19(8-9):825-35. doi: 10.1016/j.phymed.2012.02.013. Epub 2012 Mar 29. PMID: 22464012.
8. Koulivand PH, Khaleghi Ghadiri M, Gorji A. Lavender and the nervous system. Evid Based Complement Alternat Med. 2013;2013:681304. doi: 10.1155/2013/681304. Epub 2013 Mar 14. PMID: 23573142; PMCID: PMC3612440.
9. Cavanagh HM, Wilkinson JM. Biological activities of lavender essential oil. Phytother Res. 2002 Jun;16(4):301-8. doi: 10.1002/ptr.1103. PMID: 12112282.
10. Lehrner J, Marwinski G, Lehr S, Johren P, Deecke L. Ambient odors of orange and lavender reduce anxiety and improve mood in a dental office. Physiol Behav. 2005 Sep 15;86(1-2):92-5. doi: 10.1016/j.physbeh.2005.06.031. PMID: 16095639.
11. Diego MA, Jones NA, Field T, Hernandez-Reif M, Schanberg S, Kuhn C, McAdam V, Galamaga R, Galamaga M. Aromatherapy positively affects mood, EEG patterns of alertness and math computations. Int J Neurosci. 1998 Dec;96(3-4):217-24. doi: 10.3109/00207459808986469. PMID: 10069621.
12. Kritsidima M, Newton T, Asimakopoulou K. The effects of lavender scent on dental participant anxiety levels: a cluster randomised-controlled trial. Community Dent Oral Epidemiol. 2010 Feb;38(1):83-7. doi: 10.1111/j.1600-0528.2009.00511.x. Epub 2009 Nov 23. PMID: 19968674.
13. Lehrner J, Eckersberger C, Walla P, Pötsch G, Deecke L. Ambient odor of orange in a dental office reduces anxiety and improves mood in female participants. Physiol Behav. 2000 Oct 1-15;71(1-2):83-6. doi: 10.1016/s0031-9384(00)00308-5. PMID: 11134689.
14. Venkataramana M, Pratap KVN, Padma M, Kalyan S, Reddy AA, Sandhya P. Effect of aromatherapy on dental participant anxiety: a randomized controlled trial. J Indian Assoc Public Health Dent. 2016;14(2):131–134. doi: 10.4103/2319-5932.183805
15. Alkanan SAM, Alhaweri HS, Khalifa GA, Ata SMS. Dental pain perception and emotional changes: on the relationship between dental anxiety and olfaction. BMC Oral Health. 2023 Mar 26;23(1):175. doi: 10.1186/s12903-023-02864-9. PMID: 36966288; PMCID: PMC10040111.
16. Steenen SA, Linke F, van Westrhenen R, de Jongh A. Interventions to reduce adult state anxiety, dental trait anxiety, and dental phobia: A systematic review and meta-analyses of randomized controlled trials. J Anxiety Disord. 2024 Jul;105:102891. doi: 10.1016/j.janxdis.2024.102891. Epub 2024 Jun 24. PMID: 38945067.
17. Nardarajah D, Dhanraj M, Jain AR. Effects of lavender aromatherapy on anxiety levels of patients undergoing mandibular third molar extraction. Drug Invention Today. 2018;10(7):1318–1322.
18. Armfield JM, Heaton LJ. Management of fear and anxiety in the dental clinic: a review. Aust Dent J. 2013 Dec;58(4):390-407; quiz 531. doi: 10.1111/adj.12118. PMID: 24320894.
19. Premkumar KS, Aafaque S, Sumalatha S, Narendran N. Effect of Aromatherapy on Dental Anxiety Among Orthodontic Participants: A Randomized Controlled Trial. Cureus. 2019 Aug 2;11(8):e5306. doi: 10.7759/cureus.5306. PMID: 31592362; PMCID: PMC6773455.
20. Karan NB. Influence of lavender oil inhalation on vital signs and anxiety: A randomized clinical trial. Physiol Behav. 2019 Nov 1;211:112676. doi: 10.1016/j.physbeh.2019.112676. Epub 2019 Sep 7. PMID: 31505191.
21. Geethika B, Bennis MA. Evaluation of the comfort level of participants in clinics with variation in fragrances. Drug Invent Today. 2018;10:223–229.
22. Lis-Balchin M, Hart S. Studies on the mode of action of the essential oil of lavender (Lavandula angustifolia P. Miller). Phytother Res. 1999 Sep;13(6):540-2. doi: 10.1002/(sici)1099-1573(199909)13:6<540::aid-ptr523>3.0.co;2-i. PMID: 10479772.
23. Bradley BF, Brown SL, Chu S, Lea RW. Effects of orally administered lavender essential oil on responses to anxiety-provoking film clips. Hum Psychopharmacol. 2009 Jun;24(4):319-30. doi: 10.1002/hup.1016. PMID: 19382124.
24. Benedetti F. Placebo effects: from the neurobiological paradigm to translational implications. Neuron. 2014 Nov 5;84(3):623-37. doi: 10.1016/j.neuron.2014.10.023. Epub 2014 Nov 5. PMID: 25442940.
25. Colloca L, Miller FG. Role of expectations in health. Curr Opin Psychiatry. 2011 Mar;24(2):149-55. doi: 10.1097/YCO.0b013e328343803b. PMID: 21248640.
26. Mousavi SA, Nasiri F, Kashani MSA, Ghazalgoo A, Iranmanesh P, Shahbazi S. Effects of Music and Aromatherapy on Blood Pressure and Heart Rate Among Endodontic Participants: A Randomized Clinical Trial. Clin Exp Dent Res. 2025 Jun;11(3):e70156. doi: 10.1002/cre2.70156. PMID: 40497523; PMCID: PMC12152766.
27. Razavian H, Mazaheri M, Shiri A. Effect of Lavender Oral Drops in Reducing Dental Anxiety Among Participants Requiring Endodontic Treatment: A Randomised Clinical Trial. Eur

Endod J. 2025 Jan;10(1):66-72. doi: 10.14744/eej.2024.06641. PMID: 40145478; PMCID: PMC11971705.
28. Bozkurt P, Vural Ç. Effect of Lavender Oil Inhalation on Reducing Presurgical Anxiety in Orthognathic Surgery Participants. J Oral Maxillofac Surg. 2019 Dec;77(12):2466.e1-2466.e7. doi: 10.1016/j.joms.2019.08.022. Epub 2019 Sep 5. PMID: 31574261.
29. Czakert J, Kandil FI, Boujnah H, Tavakolian P, Blakeslee SB, Stritter W, Dommisch H, Seifert G. Scenting serenity: influence of essential-oil vaporization on dental anxiety - a cluster-randomized, controlled, single-blinded study (AROMA_dent). Sci Rep. 2024 Jun 19;14(1):14143. doi: 10.1038/s41598-024-63657-w. PMID: 38898054; PMCID: PMC11187188.
30. Matos YR, Nascimento MFDS, Gomes MCM, de Almeida JES, Barros Silva PG, Cetira Filho EL. Aromatherapy on Anxiety, Pain, and Quality of Life Following Surgery of Mandibular Third Molars: A Randomized, Double-Blind Clinical Trial. J Oral Maxillofac Surg. 2025 Jun;83(6):748-756. doi: 10.1016/j.joms.2025.03.003. Epub 2025 Mar 8. PMID: 40147494.
31. Herz RS. Aromatherapy facts and fictions: a scientific analysis of olfactory effects on mood, physiology and behavior. Int J Neurosci. 2009;119(2):263-90. doi: 10.1080/00207450802333953. PMID: 19125379.
32. Santos, S. C., & Silva, D. R. (1997). Adaptação do State-Trait Anxiety Inventory (STAI) – Form Y para a população portuguesa: Primeiros dados. Revista Portuguesa de Psicologia, 32, 85-98.
33. Lopes P. Ansiedad en Medicina Dentaria: validación de versiones portuguesas del “Dental Fear Survey” y del “Modified Dental Anxiety Scale” en estudantes de enseñanza superior [dissertation]. Badajoz: Universidad de Extremadura; 2009.
34. Likert, R. (1932). A technique for the measurement of attitudes. Archives of Psychology, 140, 1–55.