Tastan Eroglu *et al. BMC Oral Health* (2025) 25:321
https://doi.org/10.1186/s12903-025-05702-2

RESEARCH

Open Access

Impact of non-surgical periodontal therapy on self-perceived halitosis, and the senses of smell and taste: a prospective clinical study

Zeynep Tastan Eroglu[1*], Muhammed Emin Kalender[1], Fatma Ucan Yarkac[1], Osman Babayigit[1] and Dilek Ozkan Sen[1]

Abstract

Background Periodontal diseases could cause halitosis and may impair taste and smell. While non-surgical periodontal therapy is known to reduce halitosis, its effects on taste and smell are less studied. This study aims to investigate the factors influencing self-perceived halitosis, taste, and smell, as well as the changes in these perceptions after periodontal therapy.

Methods A total of 183 participants were divided into three groups: 61 patients with periodontitis, 61 with gingivitis, and 61 who were gingivally healthy. Periodontal parameters and self-perceived halitosis, taste, and smell were evaluated at baseline and four weeks after non-surgical periodontal treatment using a visual analog scale (VAS). Robust regression analysis was used to assess independent variables influencing baseline VAS ratings.

Results The periodontitis group had the lowest taste perception and the highest self-perceived halitosis scores ($p < 0.05$). Taste perception was negatively associated with ≥ 4 mm pockets ($p = 0.002$). A positive relationship was also observed between the plaque index and self-perceived halitosis ($p = 0.030$). Post-treatment, taste perception improved significantly in all groups ($p < 0.05$), in parallel with improvements in periodontal parameters. Additionally, self-perceived halitosis showed a significant decrease ($p < 0.05$). The improvement in smell perception was statistically significant in the gingivally healthy and periodontitis groups ($p < 0.05$).

Conclusions Periodontal disease may contribute to the development of chemosensory disorders. While the main goal of periodontal treatment is disease management, it can also improve taste and smell function. Oral hygiene practices play an essential role in the development of these improvements. However, further research is needed on the subject.

Trial registration The study was registered as "Investigation of Halitosis, Taste, and Smell in Terms of Periodontal Condition Stated by Patients and Periodontal Diagnosis by Dentists, and Then Evaluation of Change Before and After Treatment" with the registration number NCT06063460 (13/09/2023) at https://www.clinicaltrials.gov Protocol Registration and Results System.

*Correspondence:
Zeynep Tastan Eroglu
dt.zeyneptastan@gmail.com
Full list of author information is available at the end of the article

Clinical trial registration This clinical trial was registered prior to participant recruitment on ClinicalTrials.gov (NCT06063460,13.09.2023).

Keywords Chemosensory disorders, Periodontal diseases, Periodontitis, Halitosis, Smell, Taste, Non-surgical periodontal therapy, Visual analog scale

Background

Chemical stimuli, such as tastes and smells, activate chemosensory mechanisms, which pertain to the perception of taste and smell [1]. Although systemic causes are often behind chemosensory disorders, these conditions can frequently be linked to oral and dental problems [2]. Such issues include but are not limited to, trauma from anesthesia or oral surgery, medications affecting salivary excretion, and inflammatory diseases [3]. Additionally, poor oral hygiene, associated with high microorganism levels, has been connected to a diminished ability to taste [4].

The exact mechanisms through which oral inflammation affects the senses of smell and taste remain unclear. Biologically, three factors need to be considered: inflammatory molecules and increased proteolytic activity due to oral inflammation like periodontitis can induce apoptosis and diminish the variety of taste buds on the tongue; the buildup of lingual biofilm or coating can serve as a physical barrier, preventing taste buds from contacting taste molecules; and a distorted sense of smell might occur due to the putrefaction of bacterial organic compounds from periodontal lesions, leading to olfactory disturbances [5–7].

Periodontitis is a pathological condition characterized by inflammation that causes damage to the tissues that support the teeth. The condition is characterized by typical indications such as gingival bleeding, pockets around the teeth, halitosis, and a biofilm on the tongue [8]. Although halitosis is commonly associated with periodontitis, many individuals with periodontal disease may not be aware of their bad breath [9].

There are a limited number of studies examining the relationship between periodontitis and chemosensory disorders, and some have suggested that there may be a connection between them [5, 10]. In a unique study based on self-reported data, it was found that periodontitis may lead to distortions in taste and smell perceptions, potentially contributing to an increase in halitosis [7]. However, in this study, both periodontal health and disease were assessed through self-reported measures, without utilizing clinical and radiographic parameters for diagnosis.

Non-surgical periodontal therapy has been shown to reduce periodontal inflammation and bacterial load, effectively decreasing volatile sulfur compounds (VSCs), which are major contributors to halitosis [11–13]. However, its effects on taste and smell perception remain underexplored.

Although there are objective methods to assess halitosis and chemosensory disorders [14, 15], they may not fully reflect the patient's personal experience. Patient-reported outcome measures play a crucial role in clinical research by supplementing objective clinical observations. These tools are essential for evaluating the quality of care and can offer significant insights into improving patient-centered outcomes [16, 17]. Additionally, patient-reported experiences, such as understanding treatment information and being involved in therapy decisions, have been closely linked to self-reported health outcomes and adherence to treatment protocols, as shown in various medical studies [18, 19]. In the context of periodontal disease, patient self-reported measures of halitosis and chemosensory disorders provide valuable insights into the patient's subjective experience, which may not always align with instrumentally diagnosed conditions.

Studies from North America, Europe, Asia, and other regions have reported self-perceived halitosis prevalence rates ranging from 20% to over 60% [20]. Additionally, in a related study, 23% of individuals reported smell alterations, and 19% reported taste alterations [1]. Given the widespread nature of these conditions, it is crucial to investigate their underlying causes, particularly periodontal health, and develop effective treatment strategies to manage them.

The hypothesis of this study is that periodontal therapy may improve chemosensory functions by reducing inflammation and biofilm accumulation, highlighting the importance of periodontal treatment not only for oral health but also for enhancing sensory perception. The objective of this study is to assess the presence of halitosis, as well as the perception of taste and smell, in patients diagnosed with periodontitis, gingivitis, and gingival health based on clinical parameters and to investigate the impact of non-surgical periodontal therapy on halitosis and the impairment of taste and smell perception.

Methods

Study design and population characteristics

This longitudinal prospective study was conducted to evaluate the effects of periodontal diseases on self-perceived halitosis and the senses of taste and smell. In this study, a total of 183 participants from the Periodontology Department were recruited and classified into three groups according to the 2017 criteria [21]: gingivally healthy ($n=61$), gingivitis ($n=61$), and periodontitis ($n=61$), based on the periodontal examination performed at baseline (Fig. 1).

This study was carried out following the approval from the Faculty of Dentistry Ethics Committee (2023/315) and adhered to the 1975 Helsinki Declaration as amended in 2013. Participants were informed about the research objectives and the potential risks associated with non-surgical periodontal therapy, including temporary discomfort, gum sensitivity, and minor bleeding. Written consent was obtained before the commencement of the study, ensuring that all participants fully understood the nature of the treatment and had the opportunity to ask any questions. This study fully complied with the Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) checklist [22]. The research was also registered at ClinicalTrials.gov (NCT06063460, 13 September 2023).

One of the researchers (Z.T.E) recruited participants for the study sequentially from those visiting the Periodontology Clinic who met the following criteria: (1) age between 18–65 years; (2) non-smokers; (3) no dental scaling or root surface correction in the past 6 months; (4) having at least 20 teeth; (5) not pregnant or

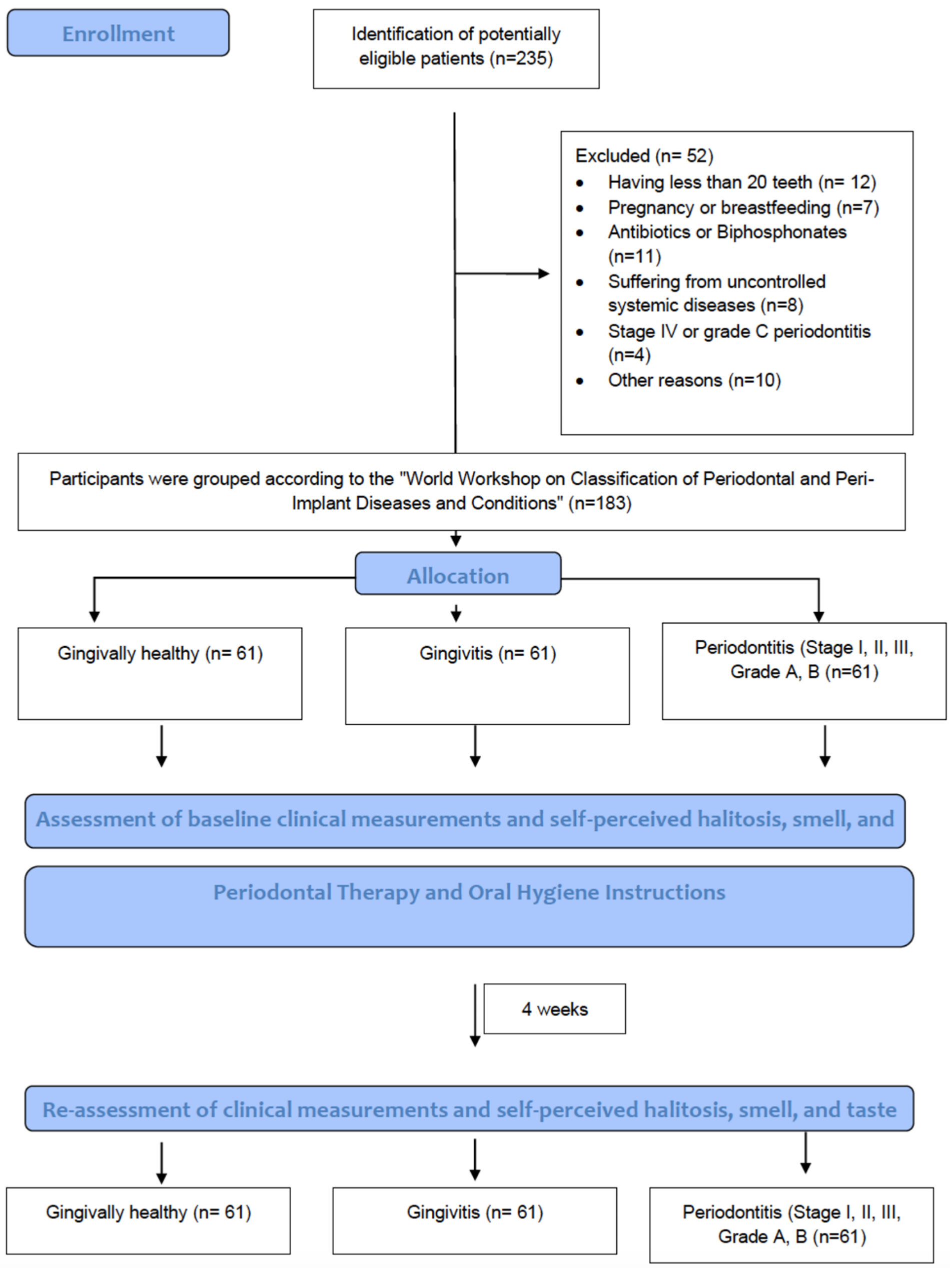

Fig. 1 Flowchart of study design

breastfeeding; (6) not on medications that affect bone metabolism, nor suffering from degenerative bone diseases like hyperparathyroidism or osteoporosis; (7) no psychiatric, mental, or physical impairments and no use of antidepressants; (8) healthy patients without any uncontrolled systemic disease (diabetes, etc.); (9) diagnosed with either gingival health, gingivitis or periodontitis (stages I, II, III, and grades A, B) based on the "World Workshop on the Classification of Periodontal and Peri-Implant Diseases and Conditions [23]; (10) had not taken antibiotics, nonsteroidal anti-inflammatory drugs, or corticosteroids for more than two weeks within the last three months; (11) not using mouthwash as part of their oral hygiene routine.

Participants who met these criteria were included in the study, while those who did not meet the criteria were excluded. Additionally, in our study, individuals with more advanced periodontal disease (stage IV and grade C periodontitis) were excluded due to the complex treatment requirements that could negatively affect treatment outcomes [23].

Data collection

At baseline, all participants in the study had their sociodemographic information (age, sex, educational level, household income), COVID-19 history, and oral hygiene habits recorded during a face-to-face interview. Income levels were categorized based on the national minimum wage in 2023 (₺11,402 per month). Participants with a monthly income below ₺11,402 were classified as having "low" income, those with an income between ₺11,402 and ₺22,804 as "moderate" income, and those with an income above ₺22,804 as "high" income. Educational levels were categorized into three groups: primary school or less (1–8 years), high school (9–12 years), and university (12 years or more, including both undergraduate and postgraduate degrees). Oral hygiene habits were assessed in two categories: frequency of toothbrushing (classified as once a day, twice or more a day, and never or rarely) and tongue cleaning (classified as never, once or more a day, and weekly). The English translation of this data collection form, originally conducted in Turkish, is provided in Supplementary File 1.

Periodontal Examination

Before initiating treatment and again at four weeks post-treatment, each participant in the study underwent a detailed clinical and radiographic periodontal examination conducted by a single trained and calibrated periodontist (M.E.K). To ensure precise and reproducible measurements, calibrations were performed to assess intra-examiner consistency for periodontal pocket depth (PD) and clinical attachment loss (CAL) using the Kappa–Cohen test before the study. The calibration process involved assessing three patients twice within 24 h. Calibration was considered successful if the variability between repeated PD and CAL measurements remained within 3%. The intraclass correlation coefficients ranged from 0.91 to 0.94 for PD and from 0.92 to 0.94 for CAL, indicating high reliability of the measurements [24].

Participants with 20 or more teeth, excluding third molars, underwent both clinical and radiographic assessments. Panoramic radiographs were examined, and a full-mouth clinical periodontal examination was performed. Periodontal parameters, including plaque index (PI), gingival index (GI), PD, CAL, and bleeding on probing (BOP – recorded 15 s after probing), were measured and documented [25]. These measurements were conducted using the Williams periodontal probe (Hu-Friedy, Chicago, IL). PD and CAL were assessed at six sites per tooth across all teeth, excluding the third molars. For PD measurements, the probe was positioned parallel to the tooth's vertical axis to identify the deepest point of the periodontal pocket, and the distance from the base of the pocket to the gingival margin was manually recorded to the nearest millimeter. Similarly, CAL was measured from the cementoenamel junction to the base of the pocket, and in cases where the cementoenamel junction was not visible, CAL was determined by tactile sense. Patients were diagnosed according to the 2017 World Workshop on the Classification of Periodontal and Peri-Implant Diseases and Conditions [23]. Clinical gingival health was defined by a probing depth of ≤ 3 mm, less than 10% of sites BOP, no sites with CAL, no radiographic evidence of alveolar bone destruction, and no history of periodontitis. Gingivitis was diagnosed in the absence of CAL with a PD of ≤ 3 mm (excluding pseudo pockets), BOP of more than 10%, and no radiological bone loss [26]. Periodontitis was diagnosed based on the presence of interdental CAL in two or more non-adjacent teeth or buccal CAL greater than 3 mm combined with a probing depth of ≥ 3 mm in two or more teeth. The diagnosed periodontitis cases were categorized using the stage and grade system [23]. The grade was determined using the radiographic bone loss/age ratio, with the percentage of bone loss calculated from the tooth showing the most severe bone loss relative to root length [23]. The periodontitis group includes patients in stages 1, 2, and 3, and grades A, B.

Periodontal treatment

At baseline, all participants received detailed instructions for self-administered plaque control measures, including twice-daily tooth brushing using the Bass technique and interproximal cleaning with both dental floss and interdental brushes. Additionally, participants were instructed on proper tongue cleaning techniques to reduce tongue coating, which in turn decreases halitosis. They were taught to use a tongue scraper (TePe Mun hygiene produkter AB, Malmö, Sweden) once per day, applying gentle strokes for 15 s on the dorsum of the tongue [27]. Participants were also informed that while tongue cleaning might initially trigger a gag reflex, this reaction typically diminishes with regular practice. These measures were demonstrated in person, and educational materials were provided to reinforce the instructions, which were delivered consistently to all participants to ensure a standardized approach.

In the groups with gingivitis and gingivally healthy, dental scaling, and tooth polishing were performed to remove supragingival plaque and calculus. All participants with periodontitis underwent scaling and root planning (SRP) and professional tooth polishing in a single appointment using manual (sharp sickles, Gracey, and universal curettes) and ultrasonic devices (Minipiezon Electromedical Systems EMS, Nyon, Switzerland) under local anesthesia. Four weeks after non-surgical periodontal therapy, patients in all three groups underwent a clinical re-evaluation.

Visual analog scale (VAS)

VAS is a widely used method for assessing subjective experiences, including pain, self-reported halitosis, and taste, and smell perceptions, in both clinical and research settings [7, 28, 29]. It is a practical, reliable, and valid tool, particularly suited for detecting significant changes over time [30]. Several studies conducted within the Turkish population have utilized VAS to evaluate halitosis, taste, and smell [31–34]. In this study, participants rated their sense of taste, smell, and halitosis before and four weeks after periodontal treatment. The VAS used a 100 mm vertical line, where 0 represented the absence of sensation (“no " or “no smell”) and 100 indicated the highest level of perception (“excellent taste” or “excellent smell”. Similarly, halitosis was rated from 0 (“no bad breath”) to 100 (“extremely bad breath”) [7].

Sample size calculation

The sample size was calculated based on the PD ($\alpha = 0.05$, effect size $d = 0.527$). Considering a power of 99.9% and a significance level of 5%, the computed sample size was of 183 subjects [35].

Statistical analysis

Data analysis was conducted using statistical software (SPSS version 23, IBM, Armonk, NY). The Kolmogorov-Smirnov and Shapiro-Wilk tests were employed to assess the data’s suitability for a normal distribution. Participant responses were analyzed according to their groups using chi-square analysis. A Kruskal Wallis test was used to compare measurement values across groups, and for significant results, the Mann-Whitney U test was applied as a post-hoc analysis. Bonferroni correction was applied to control for Type I errors. The Wilcoxon test was performed to compare the pre- and post-treatment values within the groups. Additionally, data were analyzed using the R program. For variables that did not follow a normal distribution, Robust Regression Analysis was employed to identify the influencing independent variables. The significance level was set at $p < 0.050$.

Results

Regarding demographic data, the sex of participants was similar among groups. Patients with periodontitis were significantly older than other groups ($p < 0.001$). Additionally, periodontitis group and had lower education levels and income level than other groups ($p < 0.001$) (Table 1). Periodontitis group were significantly more likely to belong to the low-income group, with an odds ratio (OR) of 2.98 (95% CI: 1.73–5.14) compared to the gingivally healthy group. Similarly, periodontitis patients were more likely to have a primary school education or less, with an odds ratio (OR) of 6.72 (95% CI: 3.21–14.08) compared to the gingivally healthy group.

No significant differences were found among the groups in terms of dry mouth sensation, frequency of tongue cleaning, and COVID-19 history ($p > 0.05$) (Table 2). The gingivally healthy group had the most frequent daily toothbrushing rate, while the periodontitis group had the lowest ($p < 0.001$). For the ‘Rarely or Never’ toothbrushing category, gingivitis patients had an odds ratio (OR) of 11.76 (95% CI: 0.99–140.4) and periodontitis patients had an odds ratio (OR) of 23.18 (95% CI: 2.09–256.8) compared to the gingivally healthy group, indicating a much higher likelihood of inadequate toothbrushing frequency in both gingivitis and periodontitis patients.

Periodontal clinical parameters at baseline and after periodontal treatment

The baseline and post-treatment measurements of the clinical periodontal parameters for all groups are summarized in Table 3; Fig. 2. Based on the baseline clinical assessments, the highest mean PD measurement was in the periodontitis group, showing significant differences from the other two groups ($p < 0.001$). The lowest mean PI, mean GI, and BOP scores were in the gingivally healthy group, showing significant differences from the other two groups ($p < 0.05$).

All periodontal condition groups had considerably lower mean PI and GI after non-surgical periodontal therapy ($p < 0.001$). Following non-surgical periodontal therapy, the gingivitis and periodontitis groups also showed lower mean PD and BOP values ($p < 0.001$).

Table 1 Sociodemographic distribution of groups

		Groups				Comparison by groups
		Gingivally healthy group (n = 61)	**Gingivitis (n = 61)**	**Periodontitis (n = 61)**	**Total (*n* = 183)**	**p**
Age (Mean + SD)		27.51 ± 6.52	26.56 ± 7.29	46.34 ± 10.47 [ab]	33.47 ± 12.29	< 0.001*
		n (%)	n (%)	n (%)	n (%)	
Income						< 0.001*
	Low	25(23.1)	40(37)	43(39.8)	108(59)	
	Moderate	28(54.9)	15(29.4)	8(15.7)	51(27.9)	
	High	8(33.3)	6 (25)	10(41.7)	24 (13.1)	
Sex						1.000
	Female	37(60.7)	37(60.7)	37(60.7)	111(60.7)	
	Male	24(39.3)	24(39.3)	24(39.3)	72(39.3)	
Education level						< 0.001*
	Primary school or less	4 (7.7)	11 (21.2)	37 (71.2)	52(28.4)	
	High school	19(38)	17(34)	14(28)	50(27.3)	
	University	38(46.9)	33(40.7)	10(12.3)	81 (44.3)	

Chi-Square Test; a: Significantly higher than Gingivally healthy group ($P < 0.05$); b: Significantly different from Gingivitis group ($P < 0.05$); ab: Significantly different from the Gingivally healthy group and Gingivitis groups ($P < 0.05$); *$p < 0.05$

Table 2 Descriptive frequency of the variables used in this study in relation to periodontal status

		Groups			Comparison by groups
		Gingivally healthy group (n = 61)	**Gingivitis (n = 61)**	**Periodontitis (n = 61)**	**p**
		n (%)	**n (%)**	**n (%)**	
Frequency of toothbrushing					< 0.001*
	Once a day	33(37.9)	24(27.6)	30(34.5)	
	Twice or more a day	27(39.7)	27(39.7)	14(20.6)	
	Rarely or Never	1(3.6)	10(35.7)	17(60.7)	
Frequency of tongue cleaning					0.829
	Never	40(65.6)	38(62.3)	42(68.9)	
	Once or more a day	15(24.6)	18(29.5)	16(26.2)	
	Weekly	6(9.8)	5(8.2)	3(4.9)	
Dry mouth sensation					0.276
	Mild	27(44.3)	31(50.8)	30(49.2)	
	Severe	1(1.6)	4(6.6)	6(9.8)	
	No	33(54.1)	26(42.60)	25(41.)	
COVID-19 positivity					0.384
	Yes	28(45.9)	29(47.5)	22(36.1)	
	No	33(54.1)	32(52.5)	39(63.9)	

Chi-Square Test; *$p < 0.05$

The changes in self-perceived halitosis and sense of taste and smell after periodontal treatment

The changes in VAS scores for self-perceived halitosis and sense of taste and smell measurements after periodontal treatment across all groups are summarized in Table 4; Fig. 3. Based on the baseline VAS scores, the lowest score of taste perception was in the periodontitis group ($p < 0.05$). There were no statistically significant differences in participants' baseline score of smell perception among the groups ($p > 0.05$). The group with periodontitis had the highest VAS scores on the self-perceived halitosis evaluation, whereas the group with gingivally healthy had the lowest scores ($p < 0.05$).

There were no statistically significant differences in participants' post-treatment taste and smell perception and perception of halitosis among the groups ($p > 0.05$).

Table 3 Periodontal clinical parameters at baseline and after periodontal treatment

		Gingivally healthy (*n* = 61)	Gingivitis (*n* = 61)	Periodontitis (*n* = 61)	
		Mean ± SD	**Mean ± SD**	**Mean ± SD**	**p**
Probing depth mean(mm)	baseline	1.57 ± 0.16^{A}	1.96 ± 0.02^{A}	3.16 ± 0.09 ^{B}	**< 0.001***
	4th week	1.56 ± 0.02	1.79 ± 0.04a	2.16 ± 0.12	**< 0.001***
	P	0.321	**< 0.001***	**< 0.001***	
Plaque index	baseline	0.76 ± 0.17^{A}	1.88 ± 0.06^{B}	1.98 ± 0.07^{B}	**0.001***
	4th week	0.31 ± 0.02^{A}	0.47 ± 0.04^{B}	0.31 ± 0.02	**< 0.001***
	P	**< 0.001***	**< 0.001***	**< 0.001***	
Gingival index	baseline	0.78 ± 0.15 ^{A}	1.56 ± 0.04^{B}	1.67 ± 0.04^{B}	**0.043***
	4th week	0.31 ± 0.02	0.45 ± 0.04^{A}	0.23 ± 0.01^{B}	**< 0.001***
	P	**< 0.001***	**< 0.001***	**< 0.001***	
Bleeding on probing (% of sites)	baseline	5.47 ± 1.75 ^{A}	52.45 ± 3.15	63.91 ± 3.85	**< 0.001***
	4th week	5.26 ± 1.65	3.81 ± 0.36	3.12 ± 0.4	**< 0.001***
	P	0.112	**< 0.001***	**< 0.001***	
Pocket depth of 4 mm and above (%)	baseline	-	-	26.42 ± 3.08	
	4th week	-	-	2.52 ± 1.07	
	P			**< 0.001***	
1–3 mm pocket depth (%)	baseline	100	100	73.58 ± 3.08	
	4th week	100	100	96.81 ± 1.08	
	P		-	**< 0.001***	
4–5 mm pocket depth (%)	baseline	-	-	22.90 ± 2.63	
	4th week	-	-	2.51 ± 1.07	
	P			**< 0.001***	
Pocket depth of 6 mm and above (%)	baseline	-	-	3.55 ± 1.03	
	4 h week	-	-	1.00 ± 017	
	P			**< 0.001***	

The Kruskal–Wallis test followed by the post-hoc Mann–Whitney U-test with Bonferroni correction

Wilcoxon test was performed to compare the pre-and post-treatment

values within the groups

SD: Standard Deviation

a: Significantly higher than Gingivally healthy group ($P < 0.05$);

b: Significantly different from Gingivitis group ($P < 0.05$)

ab: Significantly different from the Gingivally healthy group and Gingivitis groups ($P < 0.05$); *$p < 0.05$

Post-treatment taste perception scores showed a statistically significant increase compared to baseline scores across all periodontal condition groups ($p < 0.05$). In the gingivitis group, no statistically significant difference in smell perception was detected following treatment, although an improvement was observed ($p > 0.05$). Conversely, smell perception showed significant improvement in both the gingivally healthy and periodontitis groups ($p < 0.05$). Self-perceived halitosis exhibited a.

decrease post-treatment across all groups compared to baseline scores ($p < 0.001$).

The evaluation of self-perceived halitosis and sense of taste and smell at the beginning of the study using robust regression analysis

Independent variables affecting the baseline VAS scores of self-perceived halitosis and sense of taste and smell measurements for all status groups were analyzed using Robust Regression Analysis, and the models were found to be statistically significant (taste perception: F = 18.715; $p < 0.001$) (smell perception: F = 15.966; $p < 0.001$) (halitosis perception: F = 2.872; $p < 0.001$) (Table 5). Smell perception was found to be positively associated with taste perception ($p < 0.001$), while halitosis and ≥4 mm pockets were negatively associated with taste perception ($p = 0.002$). Patients who practiced dental hygiene by brushing their teeth at least twice daily demonstrated a notably elevated sense of taste in comparison to those who brushed only once a day or rarely ($p = 0.003$). In addition, individuals who did not practice tongue cleaning had pre-treatment taste perception scores that were 3.282 units lower than those who cleaned their tongue at least once daily ($p = 0.048$). A positive relationship was observed between the PI and self-perceived halitosis ($p = 0.030$). Other variables did not have a statistically significant effect on baseline self-perceived halitosis and sense of taste and smell ($p > 0.050$).

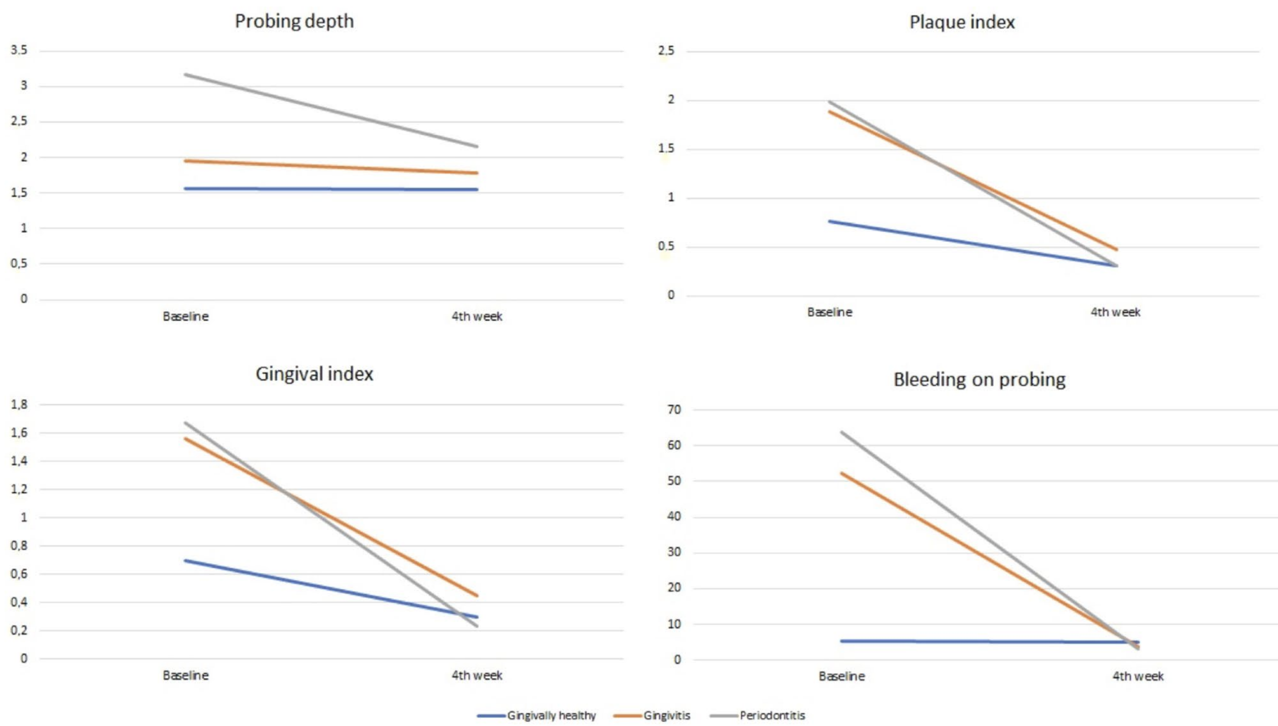

Fig. 2 Changes in periodontal clinical parameters before and after periodontal treatment in all groups

Table 4 The changes in self-reported taste, smell, and halitosis after periodontal treatment

		Gingivally healthy ($n = 61$)	Gingivitis ($n = 61$)	Periodontitis ($n = 61$)	
		Mean ± SD	**Mean ± SD**	**Mean ± SD**	**p**
Taste Perception	baseline	83.28 ± 12.74^{A}	83.93 ± 16.15^{A}	74.92 ± 20.13^{B}	**0.004**
	4th week	86.72 ± 10.44	85.90 ± 14.06	84.10 ± 17.45	0.584
	P	**0.001**	**0.039**	**< 0.001**	
Smell Perception	baseline	83.61 ± 13.04	84.75 ± 16.59	77.70 ± 23.48	0.075
	4th week	85.90 ± 12.29	86.07 ± 14.40	81.	0.310
	P	**0.002**	0.073	**< 0.001**	
Halitosis	baseline	24.92 ± 26.43^{A}	38.20 ± 30.80^{B}	42.95 ± 28.60^{C}	**0.002**
	4th week	18.85 ± 25.63	27.05 ± 26.03	24.59 ± 20.54	0.161
	P	**< 0.001**	**< 0.001**	**< 0.001**	

The Kruskal–Wallis test followed by the post-hoc Mann–Whitney U-test with Bonferroni correction; Wilcoxon test was performed to compare the pre-and post-treatment

values within the group

SD: Standard Deviation

a: Significantly higher than Gingivally healthy group ($P < 0.05$);

b: Significantly different from Gingivitis group ($P < 0.05$);

ab: Significantly different from the Gingivally healthy group and Gingivitis groups ($P < 0.05$); *$p < 0.05$

Discussion

To the best of our knowledge, this is the first study to investigate the relationship between periodontal clinical parameters and taste perception, as well as the impact of non-surgical periodontal therapy on chemosensory disorders. Our findings indicate that individuals with periodontitis exhibit a higher prevalence of halitosis and impaired senses of taste compared to other groups. Individuals with gingival health, gingivitis, and periodontitis had enhanced taste perception and less halitosis following non-surgical periodontal therapy, which included oral hygiene instructions. These findings emphasize the importance of employing appropriate statistical methods to accurately assess the observed relationships. In this study, robust regression analysis was chosen for its ability to minimize the influence of outliers, providing more reliable estimates of the effects of periodontal disease on taste perception and halitosis.

Periodontal conditions, along with individual demographic characteristics (i.e., sex, age, and education) and

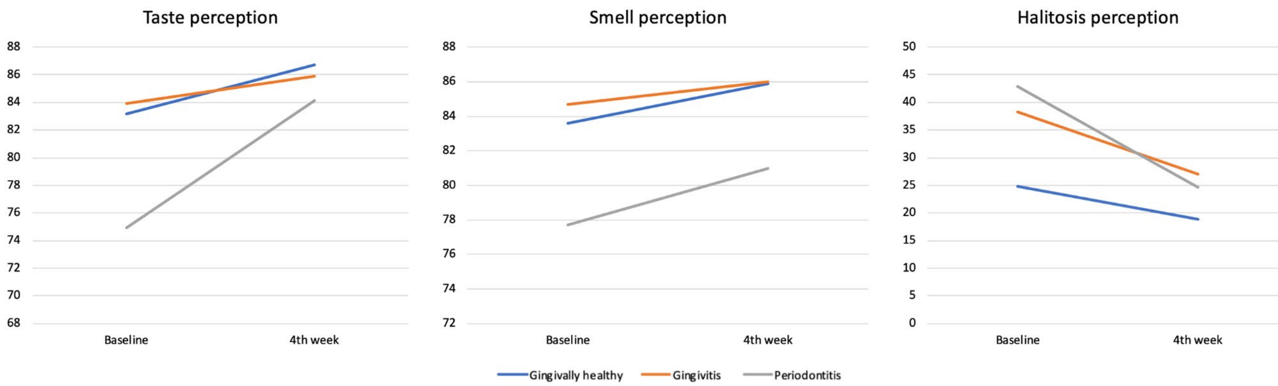

Fig. 3 Changes in Visual Analog Scale scores for halitosis, taste, and smell perception before and after periodontal treatment in all groups

habits, may influence chemosensory dysfunctions and individuals' perception of halitosis, taste, and smell. For instance, sex hormones have been shown to affect taste processing, with women generally exhibiting greater sensitivity to basic taste stimuli than men [36, 37]. Additionally, women tend to outperform men in odor identification and retronasal olfactory function [38]. These gender-related differences may have biological bases but are also shaped by social factors. Previous research indicated that women in the studied population were more frequently responsible for food selection and preparation, leading to greater experience and training in discerning smells and tastes [39, 40]. To control for potential gender-related biases, an equal distribution of men and women was ensured across all study groups.

Research suggests that inadequate oral hygiene and deteriorated periodontal health associated with an increased prevalence of halitosis complaints [41]. Recent studies have further established a significant relationship between periodontal health and halitosis, particularly in cases of periodontitis [42, 43]. For example, Aimetti et al. [42] reported higher plaque scores in individuals with halitosis, while Aliyev et al. [14] demonstrated a positive correlation between halitosis and periodontal indices such as PI, GI, PD, and CAL. Similarly, Makino et al. [44] stated that there was a significant relationship between VSCs causing halitosis and the progression of periodontal disease, the number of remaining teeth, and CAL. Another study found a significant correlation between PD and halitosis [45]. However, some studies have reported no correlation between halitosis and periodontal measurements, suggesting that the primary causes of halitosis may vary across study populations [46, 47]. The main causes of halitosis might differ in these study populations, and the varying periodontal health conditions of the participants could have influenced these different results. Our study also revealed that patients in the periodontitis group reported significantly higher levels of halitosis (42.95 ± 28.60) compared to the gingivitis (38.20 ± 30.80) and gingivally healthy groups (24.92 ± 26.43).

Periodontal conditions can also impact individuals' chemosensory perceptions, such as halitosis. There are limited studies examining the relationship between chemosensory disorders and periodontitis. Several potential mechanisms have been proposed to explain the relationship between periodontal disease and chemosensory impairments [7]. One mechanism suggests that taste buds in the lingual epithelium exhibit significant gene expression levels associated with inflammatory responses. Inflammatory molecules and increased proteolytic activity caused by oral inflammatory lesions may induce apoptosis in taste buds, altering taste perception [48].

In the present study, participants with a pocket depth of ≥ 4 mm were diagnosed with periodontitis, as this threshold is a well-established clinical indicator of the disease [21]. Given that periodontitis is a chronic inflammatory condition characterized by persistent bacterial infection and an exaggerated immune response, it may negatively influence sensory perception through sustained local and systemic inflammation [49]. Additionally, the accumulation of VSC in deeper periodontal pockets may further contribute to taste perception alteration [7].

Our study observed the lowest taste perception scores in the periodontitis group at baseline (74.92 ± 20.13) compared to the gingivitis (83.93 ± 16.15) and gingivally healthy groups (83.28 ± 12.74). Additionally, a one-unit increase in the percentage of ≥ 4 mm PD resulted in a 0.225 unit decrease in taste perception scores. This finding suggests that periodontal inflammation may contribute to taste dysfunction by altering the local inflammatory environment. However, taste perception was not affected when PD greater than 6 mm was compared with those of 4–5 mm. This indicates that while periodontitis is related to taste perception, the severity of periodontitis does not necessarily amplify this effect.

A study investigating the relationship between chemosensory impairments and periodontitis discovered a weak

Table 5 Examination of independent variables impacting self-perceived halitosis and smell and taste at baseline

Investigation of independent variables affecting pre-treatment taste perception with Robust Regression Analysis

	β 0 (95% CI)	S.E.	β 1	t	p	VIF
Fixed	28.34 (16.211–40.469)	6.142		4.614	**< 0.001***	
Age	0.043 (−0.142–0.229)	0.094	0.032	0.459	0.647	2.684
Smell Perception	0.654 (0.569–0.739)	0.043	0.686	15.191	**< 0.001***	1.129
Perception of Bad Breath	-0.077 (-0.126 - -0.028)	0.025	-0.142	-3.094	**0.002***	1.174
Plaque Index	1.98 (−1.642–5.603)	1.834	0.082	1.080	0.282	3.209
Percentage of Bleeding on Probing	-0.038 (−0.115 − 0.039)	0.039	-0.080	-0.972	0.333	3.788
≥ 4 Mm Pocket Percentage	-0.225 (-0.403 - -0.048)	0.090	-0.256	-2.506	**0.013***	5.791
Percentage of Pockets ≥ 6 Mm	0.077 (-0.38–0.535)	0.232	0.023	0.334	0.739	2.707
Do You Feel Daily Dry Mouth? (No)	Reference					
Mild	-0.343 (−3.302–2.616)	1.498	-0.011	-0.229	0.819	1.237
Severe	3.785 (−2.629–10.198)	3.248	0.056	1.165	0.246	1.270
How Often Do You Brush Your Teeth? (Rarely or Never)	Reference					
Once a day	0.9 (−3.614–5.414)	2.286	0.020	0.394	0.694	1.397
≥ 2 a day	4.836 (1.723–7.948)	1.576	0.148	3.068	**0.003***	1.295
Do you perform tongue cleaning? (1 or more a day)	Reference					
Weekly	2.746 (−2.869–8.361)	2.843	0.045	0.966	0.336	1.205
Never	-3.282 (-6.539 - -0.024)	1.649	-0.092	-1.990	**0.048***	1.186
Have You Tested Positive for Covid-19? (No)	Reference					
Yes	-2.119 (−4.994 − 0.756)	1.456	-0.066	-1.456	0.147	1.146

F = 18.715, $p < 0.001$, $R^2 = 70.94\%$, S.E: Standard error, β0: Unstandardized beta coefficient, β1: Standardized beta coefficient

Investigation of independent variables affecting pre-treatment smell perception with Robust Regression Analysis

	β 0 (95% CI)	S.E.	β 1	t	p	VIF
Fixed	17.129 (3. 61–30.648)	6.846		2.502	**0.013***	
Age	-0.17 (−0.372 − 0.032)	0.102	-0.120	-1.666	0.098	2.581
Taste Perception	0.847 (0.746–0.949)	0.051	0.856	16.530	**< 0.001***	1.330
Perception of Bad Breath	0.04 (−0.014–0.094)	0.028	0.071	1.455	0.148	1.192
Plaque Index Before Treatment	-1.258 (−5.269–2.754)	2.032	-0.050	-0.619	0.537	3.231
Percentage of Bleeding on Probing	0.038 (−0.047–0.123)	0.043	0.077	0.883	0.378	3.770
≥ 4 Mm Pocket Percentage	0.048 (−0.151–0.247)	0.101	0.053	0.475	0.636	6.062

Table 5 (continued)

Percentage of Pockets ≥ 6 Mm	0.059 (− 0.463–0.581)	0.264	0.017	0.224	0.823	2.994
Do You Feel Daily Dry Mouth? (No)	Reference					
Mild	-0.407 (-3.67–2.856)	1.652	-0.012	-0.246	0.806	1.239
Severe	-5.931 (− 12.934–1.073)	3.546	-0.084	-1.672	0.096	1.258
How Often Do You Brush Your Teeth? (Rarely or Never)	Reference					
Once a day	-1.799 (-6.804–3.206)	2.535	-0.038	-0.710	0.479	1.392
≥ 2 a day	-1.181 (− 4.699–2.338)	1.782	-0.035	-0.663	0.508	1.354
Do you perform tongue cleaning? (1 or more a day)	Reference					
Weekly	-0.018 (− 6.178–6.143)	3.120	0.000	-0.006	0.996	1.220
Never	1.752 (− 1.872–5.375)	1.835	0.047	0.955	0.341	1.194
Have You Tested Positive for Covid-19? (No)	Reference					
Yes	1.352 (− 1.802–4.506)	1.597	0.041	0.847	0.399	1.139
F = 15.966, $p < 0.001$, R^2 = 67.56%, S.E: Standard error, β0: Unstandardized beta coefficient, β1: Standardized beta coefficient						
Investigation of independent variables affecting pre-treatment Halitosis perception with Robust Regression Analysis						
	β 0 (95% CI)	S.E.	β 1	t	p	VIF
Fixed	60.19 (26.269–94.111)	17.177		3.504	**0.001**	
Age	0.104 (− 0.398–0.607)	0.254	0.046	0.410	0.682	2.772
Taste Perception	-0.725 (− 1.058 - -0.393)	0.168	-0.429	-4.308	**< 0.001**	2.198
Smell Perception	0.246 (− 0.039–0.531)	0.144	0.158	1.703	0.091	1.910
Plaque Index	11.069 (1.06–21.078)	5.069	0.262	2.184	**0.030**	3.172
Percentage of Bleeding on Probing	-0.082 (− 0.295 – 0.131)	0.108	-0.099	-0.762	0.447	3.711
≥ 4 Mm Pocket Percentage	-0.018 (− 0.495 – 0.459)	0.242	-0.012	-0.074	0.941	5.810
Percentage of Pockets ≥ 6 Mm	-0.15 (− 1.434–1.135)	0.650	-0.025	-0.230	0.818	2.647
Do You Feel Daily Dry Mouth? (No)	Reference					
Mild	1.318 (− 6.928–9.563)	4.175	0.024	0.316	0.753	1.226
Severe	10.913 (− 6.408–28.233)	8.771	0.092	1.244	0.215	1.196
How Often Do You Brush Your Teeth? (Rarely or never)	Reference					
Once a day	-1.771 (− 14.326–10.783)	6.357	-0.022	-0.279	0.781	1.420
≥ 2 a day	-0.579 (− 9.528–8.371)	4.532	-0.010	-0.128	0.899	1.345
Do you perform tongue cleaning? (1 or more a day)	Reference					
Weekly	-2.034 (− 17.324–13.256)	7.742	-0.019	-0.263	0.793	1.191
Never	-1.118 (− 10.271–8.035)	4.635	-0.018	-0.241	0.810	1.195
Have You Tested Positive for Covid-19? (No)	Reference					
Yes	-3.875 (− 11.876–4.127)	4.052	-0.069	-0.956	0.340	1.140
F = 2.872, $p < 0.001$. R2 = 27.25%, S.E: Standard error, β0: Unstandardized beta coefficient, β1: Standardized beta coefficient						

Robust Regression Analysis; *$p < 0.05$

association between periodontitis and smell impairment [10]. Our study found no significant difference in baseline sense of smell among the different groups based on periodontal health ($p > 0.05$); however, the periodontitis group had the lowest scores (67.45 ± 15.32), suggesting a possible but limited impact of periodontitis on olfactory function.

Another mechanism suggests that the presence of a biofilm on the tongue could serve as a physical barrier, preventing direct interaction between taste molecules and tongue receptors. By-products of bacterial metabolism can alter the concentration of taste molecules near the receptors, thereby affecting taste perception through sensory adaptation [50]. The study conducted by Kaur et al. [51] examined the self-reported intensity of bitter and sweet taste perceptions in connection to oral hygiene behaviors. The findings revealed that those who reported higher mean intensity scores for both tastes tended to participate in more regular oral hygiene practices, including teeth brushing and tongue cleaning. Our study found that participants who did not participate in tongue cleaning had pre-treatment taste perception scores that were 3.282 units lower than those who cleaned their tongue once or more daily, according to robust regression analysis.

The final potential mechanism proposes that bacteria can also impair taste and smell sensitivity through halitosis by producing VSCs from periodontal lesions and organic compounds on the tongue [6]. Oral biofilm formation plays a significant role in the development of oral malodor, with the production of VSCs by specific bacterial species being the primary cause of intraoral halitosis [52]. VSCs have been shown to induce apoptosis in cell types such as fibroblasts and keratinocytes [2]. Our research identified that each one-unit increase in the pre-treatment PI value corresponded to an 11.069-unit increase in pre-treatment self-perceived halitosis scores. An increase of one unit in the pre-treatment perception of halitosis results in a decrease of 0.077 units in the pre-treatment taste perception value ($p = 0.002$). Additionally, people who brushed their teeth at least twice a day had a pre-treatment taste perception value that was 4.836 units greater than those who brushed their teeth once a day or rarely.

Periodontal therapy likely reduces halitosis and improves taste and smell perception by addressing plaque accumulation, inflammation, and VSC levels. Silveira et al. [13] found that initial periodontal treatment in patients with periodontitis yielded positive results in terms of enhancing periodontal clinical parameters, decreasing VSC levels, and alleviating halitosis, findings supported by other systematic reviews [11]. In a study, it was reported that patients with deeper periodontal pockets may have higher concentrations of VSCs, including methyl mercaptan, compared to those with healthier periodontal conditions [11]. The observed reduction in PD in our study likely contributed to a decrease in these VSC levels, which are known contributors to halitosis and altered taste perception. Moreover, the reductions in PD, BOP, and GI reflect a decrease in periodontal and gingival inflammation [53]. This decrease in inflammation could be responsible for the improvements seen in chemosensory perceptions, as less inflammation may lead to enhanced function of taste buds and olfactory receptors. Periodontal inflammation can alter the local cytokine environment, disrupting taste receptor cell renewal and olfactory neuron function [7]. Specifically, Tumor Necrosis Factor-alpha may affect progenitor cell differentiation and induce apoptosis, contributing to taste dysfunction in periodontitis [48]. Additionally, the decrease in PI is indicative of improved oral hygiene and is likely associated with a reduction in bacterial biofilm and VSC levels [14]. The combined effects of reduced inflammation, improved oral hygiene, decreased VSC levels, and reduced PD may have significantly contributed to the observed improvements in self-reported halitosis, taste, and smell perception following periodontal treatment.

At the beginning of the study, all participants received instructions for oral hygiene, which included tooth brushing, interdental cleaning, and tongue cleaning. The significant improvement in taste perception observed in all groups by the end of the study, compared to the baseline, is believed to be largely attributable to the oral hygiene instructions provided. Additionally, regular tongue cleaning can help reduce the biofilm on the tongue, which is a significant source of VSCs [54]. Through the reduction of tongue coating, tongue cleaning may further contribute to the observed improvements in halitosis and sensory perceptions.

One of the major strengths of our study is its comprehensive approach, using clinical measurements for a more accurate diagnosis of periodontal disease compared to prior research that relied on self-perceived assessments [7]. Additionally, this is the first study to evaluate the impact of non-surgical periodontal therapy on sense of taste and smell.

Despite the strengths of this study, certain limitations must be acknowledged. Factors such as dietary habits, stress levels, genetic predispositions, and cultural as well as environmental influences could potentially affect the perception of halitosis and chemosensory experiences, including taste and smell [55–58]. Although relevant confounding variables were addressed in the analysis, the inherent nature of observational studies makes it challenging to entirely eliminate residual confounding, particularly regarding stress and dietary patterns.

The single-center design and the relatively homogeneous demographic background of the participants are notable limitations of this study, potentially restricting the generalizability of the findings to broader populations with diverse geographical or demographic characteristics [51, 59]. Epidemiological studies have demonstrated significant variation in chemosensory impairments, such as smell and taste disorders, across ethnic and cultural groups. For example, non-Hispanic Black and Mexican American populations show a higher prevalence of smell impairments compared to White Americans, while disparities in taste perception have been noted among Hispanics, African-Americans, and non-Hispanic Whites [60, 61]. Furthermore, dietary patterns, regional environmental factors, and oral hygiene practices may also contribute to differences in chemosensory perceptions and self-reported halitosis across populations.

Self-reported information is widely acknowledged as a reliable method for assessing halitosis and taste and smell disorders in various populations [7, 8, 59]. Nevertheless, the lack of objective measurements, such as VSC quantification through Gas Chromatography devices (e.g., Oral Chroma) or instruments like Halimeter®, represents a limitation of this study. Additionally, organoleptic assessments, widely regarded as the gold standard for halitosis evaluation, were not employed in this study, which constitutes another limitation [62]. The incorporation of such advanced methodologies alongside subjective assessments could enhance the validity of self-reported data and provide deeper insights into the mechanisms underlying halitosis and chemosensory impairments.

It is essential to highlight that the observed improvements in halitosis, taste, and smell perception in this study may be jointly influenced by both the non-surgical periodontal therapy and the oral hygiene instructions provided to the patients, which included tooth brushing and tongue cleaning known to effectively reduce bacterial biofilm and VSC.

In this study, we focused on evaluating the short-term effects of periodontal therapy. However, a four-week follow-up may not capture the long-term impact on chemosensory perceptions.

Future research should aim to incorporate objective measures, including microbiological assessments and VSC quantification, to clarify the mechanisms connecting periodontal disease with chemosensory impairments. Organoleptic assessments, widely regarded as the gold standard for halitosis evaluation, should also be integrated to enhance data reliability. Studies conducted across multiple centers, with longer observation periods and consideration of other confounders, are also needed to improve the external validity of findings. Including participants with diverse geographical, cultural, and demographic backgrounds could further address the limitations of single-center studies. Additionally, investigating the specific effects of dental hygiene practices on improving halitosis, taste, and smell, independent of other factors, would provide valuable insights. Longitudinal studies exploring the long-term effects of periodontal therapy on chemosensory perceptions, coupled with advanced quantitative methods such as validated instruments for taste and smell assessment, could further strengthen the evidence base for these findings. Future longitudinal studies should focus on the temporal mechanisms of chemosensory changes after periodontal therapy. Repeated measures over extended periods and the inclusion of control groups with varying periodontal health statuses could provide valuable insights into the progression and resolution of these impairments, offering a comprehensive framework to understand their long-term interactions with periodontal therapy.

In conclusion, periodontal disease contributes to chemosensory disorders. Periodontal treatment not only manages the disease but also improves taste and smell perception by reducing inflammation and VSC levels. Consistent oral hygiene is crucial for sustaining these benefits.

Abbreviations

BOP	Bleeding on Probing
CAL	Clinical Attachment Losses
GI	Gingival Index
PD	Pocket Depth
PI	Plaque Index
STROBE	Strengthening the Reporting of Observational Studies in Epidemiology
VAS	Visual Analog Scale
VSC	Volatile Sulfur Compounds

Supplementary Information

The online version contains supplementary material available at https://doi.org/10.1186/s12903-025-05702-2.

Supplementary Material 1

Acknowledgements

We would like to thank Dr. Naci Murat, the founder of https://eistatistik.com, for the statistical analyses of our data.

Author contributions

Z.T.E and F.U.C contributed to the study's conception and design. M.E.K, O.B, and D.O.S contributed to data acquisition, analysis, and interpretation. F.U.C conducted several statistical analyses. Z.T.E and M.E.K wrote the manuscript. O.B and D.O.S the manuscript critically for important intellectual content. All authors approved the final version of the manuscript and are accountable for all aspects of the work.

Funding

There was no financial support to perform this study.

Data availability

The datasets used and/or analysed during the current study are available from the corresponding author on reasonable request.

Declarations

Ethics approval and consent to participate
The study protocol was in accordance with the Declaration of Helsinki of 1975 was submitted to and approved by the ethical committee of Necmettin Erbakan University Faculty of Dentistry (Protocol No: 2023/315). Participants were enrolled in the study following their review and signature on the written informed consent, consistent with the principles of the Declaration of Helsinki.

Consent for publication
Not applicable.

Competing interests
The authors declare no competing interests.

Author details
[1]Department of Periodontology, Necmettin Erbakan University Faculty of Dentistry, Konya, Turkey

Received: 3 August 2024 / Accepted: 20 February 2025
Published online: 28 February 2025

Referances

1. Rawal S, Hoffman HJ, Bainbridge KE, Huedo-Medina TB, Duffy VB. Prevalence and risk factors of Self-Reported smell and taste alterations: results from the 2011–2012 US National health and nutrition examination survey (NHANES). Chem Senses. 2016;41(1):69–76.
2. Batisse C, Bonnet G, Eschevins C, Hennequin M, Nicolas E. The influence of oral health on patients' food perception: a systematic review. J Oral Rehabil. 2017;44(12):996–1003.
3. Maheswaran T, Abikshyeet P, Sitra G, Gokulanathan S, Vaithiyanadane V, Jeelani S. Gustatory dysfunction. J Pharm Bioallied Sci. 2014;6(Suppl 1):S30–3.
4. Solemdal K, Sandvik L, Willumsen T, Mowe M, Hummel T. The impact of oral health on taste ability in acutely hospitalized elderly. PLoS ONE. 2012;7(5):e36557.
5. Schertel Cassiano L, Leite FRM, López R, Fjaeldstad AW, Nascimento GG. The association between halitosis and chemosensory disorders: A systematic review. Oral Dis. 2023;29(2):369–75.
6. Stuck BA, Fadel V, Hummel T, Sommer JU. Subjective olfactory desensitization and recovery in humans. Chem Senses. 2014;39(2):151–7.
7. Schertel Cassiano L, Ribeiro AP, Peres MA, Lopez R, Fjaeldstad A, Marchini L, et al. Self-reported periodontitis association with impaired smell and taste: A multicenter survey. Oral Dis. 2024;30(3):1516–24.
8. Silva MF, Cademartori MG, Leite FRM, Lopez R, Demarco FF, Nascimento GG. Is periodontitis associated with halitosis? A systematic review and meta-regression analysis. J Clin Periodontol. 2017;44(10):1003–9.
9. Eli I, Baht R, Koriat H, Rosenberg M. Self-perception of breath odor. J Am Dent Assoc. 2001;132(5):621–6.
10. Schertel Cassiano L, Jensen AB, Pajaniaye J, Lopez R, Fjaeldstad AW, Nascimento GG. Periodontitis is associated with impaired olfactory function: a clinical study. J Periodontal Res. 2025;60(1):55–63.
11. Deutscher H, Derman S, Barbe AG, Seemann R, Noack MJ. The effect of professional tooth cleaning or non-surgical periodontal therapy on oral halitosis in patients with periodontal diseases. A systematic review. Int J Dent Hyg. 2018;16(1):36–47.
12. Izidoro C, Botelho J, Machado V, Reis AM, Proenca L, Barroso H et al. Non-Surgical periodontal treatment impact on subgingival Microbiome and Intra-Oral halitosis. Int J Mol Sci. 2023;24(3).
13. Silveira JO, Costa FO, Oliveira PAD, Dutra BC, Cortelli SC, Cortelli JR, et al. Effect of non-surgical periodontal treatment by full-mouth disinfection or scaling and root planing per quadrant in halitosis-a randomized controlled clinical trial. Clin Oral Investig. 2017;21(5):1545–52.
14. Aliyev B, Pasaoglu O, Pasaoglu H, Gungor K, Guner E, Celik B, et al. Salivary beta-galactosidase, halitosis parameters in periodontal health and disease, and their changes after periodontal treatment. Aust Dent J. 2021;66(4):377–84.
15. Nørgaard HJ, Fjaeldstad AW. Differences in correlation between subjective and measured olfactory and gustatory dysfunctions after initial ear, nose and throat evaluation. Int Arch Otorhinolaryngol. 2021;25(4):e563–9.
16. Lloyd H, Jenkinson C, Hadi M, Gibbons E, Fitzpatrick R. Patient reports of the outcomes of treatment: a structured review of approaches. Health Qual Life Outcomes. 2014;12:5.
17. Mercieca-Bebber R, King MT, Calvert MJ, Stockler MR, Friedlander M. The importance of patient-reported outcomes in clinical trials and strategies for future optimization. Patient Relat Outcome Meas. 2018;9:353–67.
18. Doyle C, Lennox L, Bell D. A systematic review of evidence on the links between patient experience and clinical safety and effectiveness. BMJ Open. 2013;3(1).
19. Liss A, Wennstrom JL, Welander M, Tomasi C, Petzold M, Abrahamsson KH. Patient-reported experiences and outcomes following two different approaches for non-surgical periodontal treatment: a randomized field study. BMC Oral Health. 2021;21(1):645.
20. Dey A, Khan MAS, Eva FN, Islam T, Hawlader MDH. Self-perceived halitosis and associated factors among university students in Dhaka, Bangladesh. BMC Oral Health. 2024;24(1):909.
21. Papapanou PN, Sanz M, Buduneli N, Dietrich T, Feres M, Fine DH, et al. Periodontitis: consensus report of workgroup 2 of the 2017 world workshop on the classification of periodontal and Peri-Implant diseases and conditions. J Periodontol. 2018;89:S173–82.
22. von Elm E, Altman DG, Egger M, Pocock SJ, Gotzsche PC, Vandenbroucke JP, et al. The strengthening the reporting of observational studies in epidemiology (STROBE) statement: guidelines for reporting observational studies. Lancet. 2007;370(9596):1453–7.
23. Tonetti MS, Greenwell H, Kornman KS. Staging and grading of periodontitis: framework and proposal of a new classification and case definition. J Periodontol. 2018;89(Suppl 1):S159–72.
24. Schwarz F, Claus C, Becker K. Correlation between horizontal mucosal thickness and probing depths at healthy and diseased implant sites. Clin Oral Implants Res. 2017;28(9):1158–63.
25. Löe H, Silness J. Periodontal disease in pregnancy I. Prevalence and severity. Acta Odontol Scand. 1963;21(6):533–51.
26. Chapple IL, Mealey BL, Van Dyke TE, Bartold PM, Dommisch H, Eickholz P, et al. Periodontal health and gingival diseases and conditions on an intact and a reduced periodontium: consensus report of workgroup 1 of the 2017 world workshop on the classification of periodontal and Peri-Implant diseases and conditions. J Periodontol. 2018;89:S74–84.
27. Acar B, Berker E, Tan C, Ilarslan YD, Tekcicek M, Tezcan I. Effects of oral prophylaxis including tongue cleaning on halitosis and gingival inflammation in gingivitis patients-a randomized controlled clinical trial. Clin Oral Investig. 2019;23(4):1829–36.
28. Sijan Gobeljic M, Milic V, Pejnovic N, Damjanov N. Chemosensory dysfunction, oral disorders and oral health-related quality of life in patients with primary Sjogren's syndrome: comparative cross-sectional study. BMC Oral Health. 2020;20(1):187.
29. Ning R, Chen J, Lu Y, Guo J. Obstructive sleep apnea: a follow-up program in its relation to temporomandibular joint disorder, sleep Bruxism and orofacial pain. BMC Oral Health. 2023;23(1):578.
30. McCormack HM, Horne DJ, Sheather S. Clinical applications of visual analogue scales: a critical review. Psychol Med. 1988;18(4):1007–19.
31. Bal KK, Alagoz S, Ozdas T, Ekici NY, Kuran G, Gorgulu O. Loss of smell in COVID-19 patients: new biomarkers. Indian J Otolaryngol Head Neck Surg. 2022;74(Suppl 2):3167–72.
32. Topan YE, Bozkurt B, Yilmaz S, Elsurer C, Gorcuyeva S, Bozkurt MK. Olfactory dysfunction in primary Sjogren's syndrome and its correlation with dry eye. Acta Otorhinolaryngol Ital. 2021;41(5):443–9.
33. Kang YJ, Cho JH, Lee MH, Kim YJ, Park CS. The diagnostic value of detecting sudden smell loss among asymptomatic COVID-19 patients in early stage: the possible early sign of COVID-19. Auris Nasus Larynx. 2020;47(4):565–73.
34. Kutsal D, Bilgin Cetin M, Durukan E, Bulut S. Evaluation of the effect of periodontitis on quality of life using Oral-Dental Health-Related quality of Life-United Kingdom scale. Int J Dent Hyg. 2021;19(3):305–12.
35. Koppolu P, Sirisha S, Penala S, Reddy PK, Alotaibi DH, Abusalim GS et al. Correlation of blood and salivary pH levels in healthy, gingivitis, and periodontitis patients before and after Non-Surgical periodontal therapy. Diagnostics (Basel). 2022;12(1).
36. Jiang RS, Chiang YF. Effect of age and gender on taste function as measured by the waterless empirical taste test. Diagnostics (Basel). 2023;13:20.
37. Uota M, Ogawa T, Ikebe K, Arai Y, Kamide K, Gondo Y, et al. Factors related to taste sensitivity in elderly: cross-sectional findings from SONIC study. J Oral Rehabil. 2016;43(12):943–52.

38. Croy I, Hoffmann H, Philpott C, Rombaux P, Welge-Luessen A, Vodicka J, et al. Retronasal testing of olfactory function: an investigation and comparison in seven countries. Eur Arch Otorhinolaryngol. 2014;271(5):1087–95.
39. Miranda MI. Taste and odor recognition memory: the emotional flavor of life. Rev Neurosci. 2012;23(5–6):481–99.
40. Nettore IC, Maione L, Desiderio S, De Nisco E, Franchini F, Palatucci G et al. Influences of age, sex and smoking habit on flavor recognition in healthy population. Int J Environ Res Public Health. 2020;17(3).
41. Herman S, Lisowska G, Herman J, Wojtyna E, Misiolek M. Genuine halitosis in patients with dental and laryngological etiologies of mouth odor: severity and role of oral hygiene behaviors. Eur J Oral Sci. 2018;126(2):101–9.
42. Aimetti M, Perotto S, Castiglione A, Ercoli E, Romano F. Prevalence Estimation of halitosis and its association with oral health-related parameters in an adult population of a City in North Italy. J Clin Periodontol. 2015;42(12):1105–14.
43. Chen X, Zhang Y, Lu HX, Feng XP. Factors associated with halitosis in White-Collar employees in Shanghai, China. PLoS ONE. 2016;11(5):e0155592.
44. Makino Y, Yamaga T, Yoshihara A, Nohno K, Miyazaki H. Association between volatile sulfur compounds and periodontal disease progression in elderly non-smokers. J Periodontol. 2012;83(5):635–43.
45. Quirynen M, Dadamio J, Van den Velde S, De Smit M, Dekeyser C, Van Tornout M, et al. Characteristics of 2000 patients who visited a halitosis clinic. J Clin Periodontol. 2009;36(11):970–5.
46. Stephen AS, Dhadwal N, Nagala V, Gonzales-Marin C, Gillam DG, Bradshaw DJ, et al. Interdental and subgingival microbiota May affect the tongue microbial ecology and oral Malodour in health, gingivitis and periodontitis. J Periodontal Res. 2021;56(6):1174–84.
47. Stamou E, Kozlovsky A, Rosenberg M. Association between oral Malodour and periodontal disease-related parameters in a population of 71 Israelis. Oral Dis. 2005;11(Suppl 1):72–4.
48. Feng P, Zhao H, Chai J, Huang L, Wang H. Expression and secretion of TNF-alpha in mouse taste buds: a novel function of a specific subset of type II taste cells. PLoS ONE. 2012;7(8):e43140.
49. Feng P, Huang L, Wang H. Taste bud homeostasis in health, disease, and aging. Chem Senses. 2014;39(1):3–16.
50. Feng Y, Licandro H, Martin C, Septier C, Zhao M, Neyraud E, et al. The associations between biochemical and Microbiological variables and taste differ in whole saliva and in the film lining the tongue. Biomed Res Int. 2018;2018:2838052.
51. Kaur K, Sculley D, Veysey M, Lucock M, Wallace J, Beckett EL. Bitter and sweet taste perception: relationships to self-reported oral hygiene habits and oral health status in a survey of Australian adults. BMC Oral Health. 2021;21(1):553.
52. Memon MA, Memon HA, Muhammad FE, Fahad S, Siddiqui A, Lee KY, et al. Aetiology and associations of halitosis: A systematic review. Oral Dis. 2023;29(4):1432–8.
53. Stando-Retecka M, Piatek P, Namiecinska M, Bonikowski R, Lewkowicz P, Lewkowicz N. Clinical and Microbiological outcomes of subgingival instrumentation supplemented with high-dose omega-3 polyunsaturated fatty acids in periodontal treatment - a randomized clinical trial. BMC Oral Health. 2023;23(1):290.
54. Silva MLV, Viana KSS, de Arruda JAA, de Miranda RD, Soares MCF, Calado HDR et al. Volatile sulfur compounds, biofilm, and salivary parameters in patients with periodontal disease: a cross-sectional study. Odontology. 2024 Sep 15.
55. Feeney EL, McGuinness L, Hayes JE, Nolden AA. Genetic variation in sensation affects food liking and intake. Curr Opin Food Sci. 2021;42:203–14.
56. Liu J, Ling JQ, Wu CD. Cetylpyridinium chloride suppresses gene expression associated with halitosis. Arch Oral Biol. 2013;58(11):1686–91.
57. De Lima PO, Nani BD, Rolim GS, Groppo FC, Franz-Montan M, De Alves AB, et al. Effects of academic stress on the levels of oral volatile sulfur compounds, halitosis-related bacteria and stress biomarkers of healthy female undergraduate students. J Breath Res. 2020;14(3):036005.
58. Li Z, Li J, Fu R, Liu J, Wen X, Zhang L. Halitosis: etiology, prevention, and the role of microbiota. Clin Oral Investig. 2023;27(11):6383–93.
59. Vali A, Roohafza H, Keshteli AH, Afghari P, Javad Shirani M, Afshar H, et al. Relationship between subjective halitosis and psychological factors. Int Dent J. 2015;65(3):120–6.
60. Liu G, Zong G, Doty RL, Sun Q. Prevalence and risk factors of taste and smell impairment in a nationwide representative sample of the US population: a cross-sectional study. BMJ Open. 2016;6(11):e013246.
61. Pinto JM, Schumm LP, Wroblewski KE, Kern DW, McClintock MK. Racial disparities in olfactory loss among older adults in the united States. J Gerontol Biol Sci Med Sci. 2014;69(3):323–9.
62. Nini W, Chen L, Jinmei Z, Lufei W, Jingmei Y. The association between halitosis and periodontitis: a systematic review and meta-analysis. Clin Oral Investig. 2024;28(6):341.

Publisher's note