scientific reports

OPEN

Oral health, smoking status, and oral manifestations of adult patients with SARS-CoV-2 during the Omicron outbreak in China: a cross-sectional study

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The incidence of oral manifestations is positively correlated with the severity of COVID-19. The Omicron is the most significant variant of SARS-CoV-2. This study aimed to explore oral manifestations of adult patients during the Omicron outbreak and the relationship between oral health care, smoking and oral manifestations. A cross-sectional study was conducted from January to March 2023 by the online platform Wenjuanxing to collect data. Univariate and multivariate logistics regression models were used to analyze influencing factors of oral manifestations. The study included 1153 adult patients. Oral manifestations were reported at 38.6%, followed by dysgeusia (38.3%), dry mouth (28.0%), halitosis (6.6%), and oral ulcers (5.4%). Previous periodontal diseases increased the risk of halitosis, but reduced the risk of dysgeusia; previous oral mucosal diseases increased the risk of dysgeusia, halitosis and oral ulcers. E-cigarette users were at a higher risk of halitosis. Exposure to secondhand smoke(SHS) reduced the risk of oral ulcers, patients who neither smoked nor was exposed had lower odds of oral ulcers and dysgeusia. This study focused on Omicron-specific oral manifestations and the effects of oral health behaviors, e-cigarettes and SHS. It is recommended to promote targeted oral hygiene campaigns and smoking cessation plans to reduce oral lesions caused by sudden public health emergencies.

Keywords SARS-CoV-2, COVID-19, Omicron, Oral manifestations, E-cigarette vapor, Secondhand smoke

The coronavirus disease 2019 (COVID-19) was caused by SARS-CoV-2 infection. The World Health Organization (WHO) declared the global COVID-19 pandemic on March 11, 2020[1], and as of February 10, 2025, there have been over 777 million confirmed cases and 7.09 million deaths worldwide[2]. Omicron was designated as a variant of concern by the WHO[3], and rapidly replaced delta as the predominant strain globally due to its infectiousness and immune evasion ability[4]. After China lifted the COVID-19 Category A infectious disease prevention and control measures from January 8, 2023, a large number of cases subsequently broke out across the country-known as the "National Omicron Outbreak"[5]. Although WHO announced that COVID-19 was no longer a

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Public Health Emergency of International Concern (PHEIC)[6], we are still in the midst of a pandemic that is demonstrating a lasting impact on public health[7,8].

COVID-19 caused various oral manifestations in both adult and pediatric patients, including oral mucosal damage, xerostomia, dysgeusia, gingivitis and so on[9–11]. It has been shown that the incidence of COVID-19-related oral manifestations is positively correlated with the severity of the infection[12], and its subsidence coincides with regression of COVID-19[13]. Oral manifestations caused pain and discomfort, and affected patients' quality of life[11]. Identifying characteristic oral manifestations can promote early recognition and treatment of the condition[14–16]. Omicron-specific oral manifestations in adults included dysgeusia, pathological tongue coating, xerostomia, oral ulcers and so on, but the incidence of various oral manifestations was slightly different from other strains[9,17–19]. All in all, oral manifestations are common after COVID-19 infection regardless of the variant strains and the study population.

Smokers experienced oral manifestations such as altered taste, tongue hairiness, sore and dry throat, white spots, and gingival inflammation[20]. Smoking history was not only a risk factor for severe COVID-19[21,22], but also more likely to lead to taste disorders after Omicron infection[19]. Previous studies have shown that the survival rate of SARS-CoV-2 might partly depend on periodontal health, oral hygiene, and dental care[23,24]. Maintaining good oral conditions prevented aspiration pneumonia and chronic obstructive pulmonary disease, reduced host susceptibility to SARS-CoV-2, and facilitated the control of infection and transmission of COVID-19[25–27], but the effect on oral manifestations was still unknown. In the study between Omicron-specific oral manifestations and influencing factors, patients who received more than three doses of COVID-19 vaccine were more likely to have dysgeusia, and patients with smell disorders and xerostomia had a significantly higher incidence of other oral manifestations[17].

The aim of this study was to explore oral manifestations of adult patients during in the Omicron dominant period in China and to determine the association of oral health care and smoking with oral manifestations, which would promote oral health during public health emergencies and provide healthcare strategies in future epidemics.

Methods

Study design and participants

A cross-sectional survey of COVID-19 infected adult patients was conducted by convenient sampling at the Third Affiliated Hospital of the Air Force Military Medical University, Xi'an, Shaanxi Province, China, from January to March 2023. The study was reported according to The Checklist for Reporting Results of Internet E-Surveys (CHERRIES) and Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) statement[28,29]. Inclusion criteria for study participants: diagnosis of COVID-19 infection, including positive nucleic acid test or antigen self-test; age ≥ 18 years; informed consent and ability to complete the questionnaire. Exclusion criteria: history of psychiatric illness; emergency; Time to fill out the questionnaire was less than 2 min or more than 30 min; questionnaire with logical errors (included contradictory responses, answers obviously not corresponding to questions, incomplete sections, choosing the same option for all questions). According to the sample size calculation method for cross-sectional studies, dysgeusia was the most common oral manifestations in COVID-19-infected patients, with a prevalence of 45%[9]. According to the sample size calculation formula for cross-sectional studies, $N = [Z^2_{\alpha/2} * p(1-p)]/d^2$, where Z is the significance test statistic, p is the incidence rate, and d is the error value. Taking 95% confidence intervals (CIs), $\alpha = 0.05$, $Z = 1.96$, $p = 45\%$, and $d = 3\%$, yielded a sample size of 1056[30].

Study measures

We distributed the questionnaire through Wenjuanxing (Ranxing Tech, Changsha), an online platform widely used by Chinese researchers. Participants accessed a link to fill out the questionnaire, which could only be filled out once by everybody, and only be submitted if it was fully completed. To ensure the representativeness of the sample, electronic questionnaires were strictly collected according to the inclusion and exclusion criteria from hospitalized and non-hospitalized patients in all clinical departments of the hospital. In addition, for elderly patients who were inconvenient to use electronic devices, professional personnels were trained to assist them in filling out questionnaires. The question-naire was self-developed by the researcher and consisted of four parts: (1) Demographic characteristics. Age, gender, marital status, education, residential district, and systemic diseases before infection; (2) Oral health care. Frequency of tooth brushing, frequency of flossing, frequency of dental scaling, use of mouthwash, previous history of oral diseases and treatment. (3) Smoking. According to the Global Adult Tobacco Survey (GATS) questionnaire[31], the investigation contents were smoking status, the type of smoking and the amount of cigarettes by smokers, secondhand smoke (SHS) exposure by non-smokers. (4) COVID-19 infection related conditions. Self-reported oral manifestations, vaccination status, and severity of COVID-19, which was categorized as asymptomatic, mild, moderate, severe and critical according to Diagnosis and Treatment Programm for COVID-19 (Tenth Edition on Trial)[32]. Before the formal survey, five experts were invited to verify the content validity of the questionnaire, ten participants were selected to test the clarity and applicability of the questionnaire for a pilot survey, which was modified according to the feedbacks to form the final version. The data from the pretest was not used for study analysis.

Statistical analysis

The software SPSS 27.0 (SPSS Inc, Chicago, IL) was used for data entry and statistical analysis. All variables were expressed as frequencies and percentages. If an item was missing from the questionnaire, the questionnaire was defined as missing and was not counted in the statistics. Univariate logistic regression analysis was used to analyze the relationship between demographic characteristics, oral health care, smoking and each oral manifestation with Omicron infection, and initially analyze potential influencing factors. Statistically significant variables were then included in multivariate logistic regression analysis to further adjust for potential confounders. If the VIF value of any independent variable was greater than 10, it was removed and regression analysis was carried out again[33]. Adjusted ORs and 95% CIs and p-values were calculated, with $p < 0.05$ indicating statistical significance.

Ethics approval
After consultation and decision by the Ethics Committee of the Third Affiliated Hospital of the Air Force Medical University, the study was exempted from ethical review, and written informed consent was waived. The study was conducted in accordance with the Declaration of Helsinki and related norms. All participants were informed study purpose prior to the investigation, and that the data would be kept confidential and could be withdrawn at any time. Participants who agreed to do so could click "Informed Consent" in the electronic questionnaire, or by withdrawing if they did not agree to do so.

Results
Participant characteristics
A total of 1283 respondents consented to participate in the survey. The study included 1153 patients who completed the questionnaire, yielding an effective response rate of 89.9%. All participants were infected with COVID-19, with a mean age of 32.45 ± 10.46 years. Detailed baseline demographic and clinical characteristics are presented in Table 1.

Variables	N (%)
Age (years)	
18–30	598 (51.9)
31–60	533 (46.2)
≥ 61	22 (1.9)
Gender	
Female	762 (66.1)
Male	391 (33.9)
Marital status	
Single	482 (41.8)
Married	657 (57.0)
Divorced/widowed	14 (1.2)
Education level	
High school or below	345 (29.9)
Bachelor's degree	686 (59.5)
Master's degree or above	122 (10.6)
Province or Territory	
Shaanxi	978 (84.8)
Shanxi	34 (3.0)
Gansu	31 (2.7)
Others	110 (9.5)
Region	
City	930 (80.6)
Urban	123 (10.7)
Rural	100 (8.7)
Physical condition	
Thyroid diseases	24 (2.1)
Hypertension	24 (2.1)
Gastrointestinal diseases	18 (1.6)
Cardiovascular diseases	13 (1.1)
Other respiratory system diseases	13 (1.1)
Asthma	10 (0.9)
Liver disease	7 (0.6)
Diabetes	7 (0.6)
Psychological diseases	6 (0.5)
No	1011 (87.7)

Table 1. Demographic characteristics of SARS-CoV-2 patients (N = 1153).

Oral health care and smoking habits

Regarding oral health status, 70.9% reported brushing their teeth twice or more times a day, 46.9% hardly flossed, 27.1% cleaned their teeth once or twice per year, and 86.0% did not use mouthwash. Eighteen percent of participants had previous oral diseases (periodontal disease and mucosal disease); 53.9% of those with a history of periodontal disease were untreated, 57.7% of those with a history of mucosal disease were untreated, and 37.8% were unsure whether they had ever had any oral diseases.

In terms of smoking status, 88.3% never smoked, of whom 55.1% were exposed to secondhand smoke (SHS)—mainly "smoking inside home" (35.2%). About 11.7% were smokers (both current and former), with 97.0% using cigarettes and 10.4% using e-cigarettes. The average smoking of cigarette users was 8.1 cigarettes/day, with 75.6% smoking ≤ 10 cigarettes/day (Table 2).

Self-reported oral manifestations and others

After infection with Omicron strains, 38.6% developed oral manifestations, followed by dysgeusia (38.3%), dry mouth (28.0%), halitosis (6.6%), and oral ulcers (5.4%). Oral ulcers mostly occurred in the buccal mucosa (40.3%) and least frequently in the palate (17.7%). Loss of taste was reported in 26% of patients with dysgeusia. A total of 93.4% of patients had been vaccinated with the COVID-19 vaccine. Mild cases accounted for 70.4%, with no critical cases reported (Table 3).

Risk factors of self-reported oral manifestations

Dry mouth

In the multivariate analysis of dry mouth (Table 4), individuals who had hypertension (adjusted odds ratio [AOR] = 3.612, 95% CI 1.120–11.651, $p < 0.05$), other respiratory diseases (AOR = 3.291, 95% CI 1.385–7.818, $p < 0.05$) were at a higher risk of dry mouth.

Halitosis

The results of the multivariable logistic regression analysis showed that psychological diseases (AOR = 3.013, 95% CI 1.024–8.866, $p < 0.05$) were associated with an increased risk of halitosis. E-cigarette users were more likely to experience halitosis (AOR = 8.236, 95% CI 1.312–51.695, $p < 0.05$) than non-smoking. Compared with those without previous oral periodontal and mucosal diseases, patients only with previous periodontal diseases (AOR = 2.330, 95% CI 1.143–4.750, $p < 0.05$) were associated with an increased odds of halitosis, as were those only with previous oral mucosal diseases (AOR = 6.419, 95% CI 2.542–16.209, $p < 0.05$) (Table 4).

Oral ulcers

Diabetes (AOR = 8.721, 95% CI 1.425–53.395, $p < 0.05$), and thyroid disease (AOR = 6.165, 95% CI 1.827–20.799, $p < 0.05$) had significantly higher odds of oral ulcers. Individuals with a history of only oral mucosal diseases (AOR = 24.484, 95% CI 9.707–61.755, $p < 0.05$) posed an increased risk for oral ulcers compared to those without previous oral diseases. Regarding SHS exposure, exposure to smoking at workplace (AOR = 0.282, 95% CI 0.096–0.832, $p < 0.05$), patients who neither were exposed to SHS nor smoked (AOR = 0.241, 95% CI 0.068–0.853, $p < 0.05$) had a lower risk of oral ulcers compared to smoking (Table 4).

Dysgeusia

Other respiratory diseases (AOR = 3.990, 95% CI 1.026–15.515, $p < 0.05$), hypertension (AOR = 2.519, 95% CI 1.005–6.316, $p < 0.05$), and obesity (AOR = 2.711, 95% CI 1.175–6.254, $p < 0.05$) were associated with an increased risk of dysgeusia. Individuals who were not exposed to SHS and do not smoke had lower odds of dysgeusia than smokers (AOR = 0.443, 95% CI 0.301–0.651, $p < 0.05$). Compared with the absence of both oral diseases, those only with previous periodontal diseases (AOR = 0.639, 95% CI 0.425–0.960, $p < 0.05$) and those who did not know if they had oral diseases (AOR = 0.663, 95% CI 0.496–0.886, $p < 0.05$) were at a reduced risk, but those only with previous mucosal diseases were at an increased risk of dysgeusia (AOR = 2.150, 95% CI 1.040–4.448, $p < 0.05$) (Table 4).

Discussion

While many studies have explored the effects of oral hygiene and smoking on the risk and severity of COVID-19, few studies investigated the impact of the two factors on the oral manifestations of SARS-CoV-2 infected patients, especially adults with Omicron infection. Our research found that although the pathogenicity of Omicron variant was weakened, oral lesion still appeared after SARS-CoV-2 infection, and further explained the importance of maintaining good oral hygiene habits to reduce the risk of oral manifestations. Different from previous studies, the study also revealed the impact of e-cigarette and secondhand smoke exposure on oral symptoms of SARS-CoV-2 infection.

In the study, mild infection was the most common type of Omicron variant infection, followed by asymptomatic and moderate, with no critical types, which was consistent with previous findings[34]. Cough was the most common symptom in non-hospitalized individuals with Omicron infection, with the incidence of 91.7%[35]. Oral lesions caused by Omicron infection were consistent, with the highest prevalence of dysgeusia (38.3%), followed dry mouth, halitosis and oral ulcers, respectively[17]. SARS-CoV-2 infection may lead to chemical sensory impairment thereby affecting taste[36]. Professor C.Hopkins[37] pointed out that taste disorder was a hallmark symptom of COVID-19 as an early indication of infection. However, some researchers have suggested that dry mouth was most common and also appeared earlier than systemic symptoms[38,39]. It is speculated that respiratory diseases and hypertension increased salivary and respiratory secretions, which promoted the spread of SARS-CoV-2 and then increased the risk of dry mouth[40]. In this study, oral ulcers were least frequent and most commonly occured on the buccal mucosa, while the prevalence of oral ulcers in pediatric patients was

Variables	N (%)
Frequency of tooth brushing	
Twice or more times daily	817 (70.9)
Once daily	302 (26.2)
Two or three times a week	27 (2.3)
Hardly	7 (0.6)
Frequency of dental floss	
Twice or more times daily	166 (14.4)
Once daily	211 (18.3)
Two or three times a week	235 (20.4)
Hardly	541 (46.9)
Frequency of dental scaling	
Once or twice per year	313 (27.1)
Occasionally	500 (43.4)
Never	340 (29.5)
Mouthwash	
Yes	161 (14.0)
No	992 (86.0)
Previous history of oral diseases	
Only periodontal diseases	156 (13.5)
Only oral mucosal diseases	39 (3.4)
Both	13 (1.1)
Neither	509 (44.2)
Not known	436 (37.8)
Periodontal treatment	
Surgical treatment	22 (13.0)
Non-surgical treatment	56 (33.1)
No	91 (53.9)
Treatment of oral mucosal diseases	
Yes	22 (42.3)
No	30 (57.7)
Smoking status	
Never smoker	1018 (88.3)
Current smoker	107 (9.3)
Former smoker	28 (2.4)
SHS exposure	
Smoking inside home	358 (35.2)
Vaping inside home	18 (1.8)
Smoking at workplace	328 (32.2)
Vaping at workplace	64 (6.3)
No exposure	383 (37.6)
Types of smoking	
Cigarette	131 (97.0)
E-cigarette	14 (10.4)
Number of cigarettes/day	
≤ 10	99 (75.6)
> 10	32 (24.4)

Table 2. Oral health care and smoking habits of SARS-CoV-2 patients (N = 1153). SHS exposure: Secondhand smoke exposure.

higher and often appeared on the tongue, which highlights age-related differences[11]. Halitosis may be caused by painful oropharyngeal wounds, as well as infections of the tonsils and soft palate leading to the accumulation of bacteria and fungi[41]. It can be seen that oral manifestations as the unique feature of SARS-CoV-2 infection, although not life-threatening, plays an important role in the early diagnosis and decision-making of SARS-CoV-2 infection, and also has a significant impact on the patient's quality of life[42,43].

Poor oral hygiene habits were the inducement of oral manifestations after SARS-CoV-2 infection[16,41,44]. The American Dental Association (ADA) recommends brushing twice a day, flossing once a day, and regular

Variables	N (%)
Oral manifestations	
Dysgeusia	442 (38.3)
Dry mouth	323 (28.0)
Halitosis	76 (6.6)
Oral ulcers	62 (5.4)
None	708 (61.4)
Site of oral ulcers	
Buccal mucosa	25 (40.3)
Tongue	19 (30.7)
Lips	17 (27.4)
Gingiva	12 (19.4)
Palate	11 (17.7)
Types of dysgeusia	
Loss of taste	115 (26.0)
Hypogeusia	327 (74.0)
Vaccination	
Yes	1077 (93.4)
No	76 (6.6)
COVID-19 severity	
Asymptomatic	85 (7.4)
Mild	812 (70.4)
Moderate	255 (22.1)
Severe	1 (0.1)
Critical	0 (0)

Table 3. Self-reported oral manifestations and others of SARS-CoV-2 patients (N = 1153).

preventive oral examinations[45]. Most of the participants in the study reported brushing their teeth twice or more times daily, but showed poor adherence to other oral care practices, such as flossing, mouthwash use, and regular dental scaling. In addition, more than half of the participants with a history of oral diseases remained untreated, and 37.8% were unsure if they had ever suffered from oral diseases. During the epidemic, routine dental cleanings and non-emergency oral disease treatments were restricted[46]. Beyond this restriction, other factors related to oral health awareness may also have contributed[47,48]. Specifically, these factors included fear of infection from dental procedures, hesitation to go out during lockdowns, and neglect of dental floss and mouthwash use.

The periodontal pocket can be used as a storage location for SARS-CoV-2. SARS-CoV-2 infected people who had received periodontal treatment developed fewer oral complications than those who had not[16]. Our study did not confirm different effects of surgical treatment, non-surgical treatment, or no treatment for periodontal diseases on oral manifestations. However, we found that individuals with a history of periodontal disease had a higher risk of halitosis after infection. This finding is consistent with Gulay Tuter's research[16]. A potential explanation is that original dental calculus and plaque may promote SARS-CoV-2 colonization and aggravate periodontal tissue infection[49]. But it reduced the risk of taste disorders, which aligns with a multi-center, large-scale study in China[15]. In addition, compared to participants who clearly knew they had no oral diseases, those unsure if they had oral diseases had a lower risk of taste disorders. This may be because individuals concerned about oral health are more sensitive to oral changes. Notably, oral mucosa is the initial entry point of SARS-CoV-2[43]. Previous oral mucosal diseases increased the risk of dysgeusia and halitosis after Omicron infection. Although previous oral mucosal diseases were statistically associated with oral ulcers, the wide confidence interval indicated high uncertainty about this relationship, which was likely due to the small subgroup size. In conclusion, it is recommended that keeping good oral conditions could prevent deterioration of oral health after SARS-CoV-2 infection, and standardized oral health care habits should be maintained or reinforced for long periods[16,27].

Smoking prevalence in the study was 9.3%, which is consistent with the domestic smoking rate (9%) in the early epidemic period of COVID-19 in 2020[50,51], lower than the smoking rate (26.7%) of the Chinese population[52]. The most common type of tobacco was cigarettes, with an average cigarette smoking of 8.1 cigarettes/day, which is lower than the reported cigarette smoking of 17.2 cigarettes/day of the Chinese population[52]. This phenomenon can be attributed to two reasons: first, people have a correct understanding of smoking aggravating SARS-CoV-2 infection and attach importance to health, and secondly, limited social interaction, frequently wearing masks and hand washing lead to the reduced convenience of buying cigarettes and smoking[51].

Smoking and e-cigarette use show different associations with oral manifestations in COVID-19 patients, and also vary with age groups. Previous studies have shown that among adolescents and young adults infected with COVID-19, both e-cigarette users and cigarette users reported dry mouth and oral ulcers, but only cigarette

Dependent variables	Independent variables	Univariate analysis		Multivariate analysis	
		AOR (95%CI)	*p*-value	AOR (95%CI)	*p*-value
Dry mouth	Other respiratory system diseases				
	No	Ref		Ref	
	Yes	3.660 (1.152–11.626)	0.028*	3.291 (1.385–7.818)	0.007*
	Hypertension				
	No	Ref		Ref	
	Yes	3.172 (1.355–7.423)	0.008*	3.612 (1.120–11.651)	0.032*
	SHS exposure				
	Smoker	Ref		Ref	
	Smoking inside home	1.128 (0.796–1.601)	0.498	1.136 (0.796–1.622)	0.482
	Vaping inside home	1.520 (0.566–4.081)	0.406	1.586 (0.588–4.283)	0.363
	Smoking at workplace	0.975 (0.683–1.392)	0.889	1.006 (0.699–1.449)	0.973
	Vaping at workplace	1.613 (0.926–2.810)	0.092	1.667 (0.951–2.921)	0.074
	No exposure	0.662 (0.442–0.991)	0.045*	0.697 (0.462–1.054)	0.087
	Frequency of dental floss				
	Hardly	Ref		Ref	
	Two or three times a week	1.285 (0.839–1.967)	0.249	1.387 (0.979–1.965)	0.066
	Once daily	1.849 (1.156–2.958)	0.010*	0.793 (0.533–1.180)	0.253
	Twice or more times daily	1.008 (0.609–1.668)	0.976	0.774 (0.502–1.193)	0.245
	Mouthwash				
	No	Ref		Ref	
	Yes	1.493 (1.033–2.159)	0.033*	1.442 (0.987–2.107)	0.058
Halitosis	Psychological diseases				
	No	Ref		Ref	
	Yes	9.608 (1.579–58.474)	0.014*	3.013 (1.024–8.866)	0.045*
	Obesity				
	No	Ref		Ref	
	Yes	3.524 (1.287–9.647)	0.014*	5.164 (0.528–50.513)	0.158
	Smoking status				
	Never smoker	Ref		Ref	
	Current smoker	2.433 (1.278–4.634)	0.007*	0.854 (0.046–15.962)	0.916
	Former smoker	1.383 (0.318–6.019)	0.665	0.314 (0.016–6.194)	0.446
	Types of smoking				
	Non-smoking	Ref		Ref	
	Cigarette	1.707 (0.877–3.321)	0.115	2.159 (0.129–36.130)	0.592
	E-cigarette	8.389 (2.030–34.688)	0.003*	8.236 (1.312–51.695)	0.024*
	Others	1.676 (0.118–23.750)	0.703	1.442 (0.100–20.790)	0.788
	Previous history of oral diseases				
	Neither	Ref		Ref	
	Both	4.229 (0.871–20.530)	0.074	3.600 (0.721–17.983)	0.119
	Only periodontal diseases	2.312 (1.143–4.677)	0.020*	2.330 (1.143–4.750)	0.020*
	Only oral mucosal diseases	7.048 (2.946–16.859)	0.000*	6.419 (2.542–16.209)	0.000*
	Not known	1.357 (0.743–2.476)	0.320	1.248 (0.674–2.312)	0.481
Continued					

Dependent variables	Independent variables	Univariate analysis		Multivariate analysis	
		AOR (95%CI)	*p*-value	AOR (95%CI)	*p*-value
Oral ulcers	Education level				
	High school or below	Ref		Ref	
	Bachelor's degree	0.584 (0.337–1.011)	0.055	0.658 (0.352–1.228)	0.189
	Master's degree or above	0.211 (0.049–0.905)	0.036*	0.244 (0.054–1.112)	0.068
	Psychological diseases				
	No	Ref		Ref	
	Yes	12.306 (1.970–73.524)	0.007*	4.811 (0.370–62.507)	0.230
	Diabetes				
	No	Ref		Ref	
	Yes	9.018 (1.617–50.310)	0.012*	8.721 (1.425–53.395)	0.019*
	Thyroid diseases				
	No	Ref		Ref	
	Yes	5.537 (1.966–15.594)	0.001*	6.165 (1.827–20.799)	0.003*
	Types of smoking				
	Non-smoking	Ref		Ref	
	Cigarette	1.709 (0.827–3.533)	0.148	0.473 (0.128–1.751)	0.262
	E-cigarette	8.345 (1.839–37.859)	0.006*	3.657 (0.452–29.575)	0.224
	SHS exposure				
	Smoker	Ref		Ref	
	Smoking inside home	0.582 (0.300–1.132)	0.111	0.431 (0.143–1.300)	0.135
	Vaping inside home	2.718 (0.734–10.063)	0.134	2.371 (0.509–11.034)	0.271
	Smoking at workplace	0.405 (0.195–0.840)	0.015*	0.282 (0.096–0.832)	0.022*
	Vaping at workplace	1.205 (0.405–3.581)	0.738	1.407 (0.421–4.703)	0.579
	No exposure	0.350 (0.163–0.750)	0.007*	0.241 (0.068–0.853)	0.027*
	Previous history of oral diseases				
	Neither	Ref		Ref	
	Both	3.161 (0.379–26.335)	0.287	2.449 (0.275–21.767)	0.422
	Only periodontal diseases	2.353 (0.984–5.625)	0.054	1.838 (0.727–4.643)	0.198
	Only oral mucosal diseases	24.835 (10.488–58.806)	0.000*	24.484 (9.707–61.755)	0.000*
	Not known	1.743 (0.850–3.576)	0.130	1.548 (0.728–3.290)	0.256
Continued					

Dependent variables	Independent variables	Univariate analysis		Multivariate analysis	
		AOR (95%CI)	*p*-value	AOR (95%CI)	*p*-value
Dysgeusia	Marital status				
	Single	Ref	–	–	
	Married	1.344 (1.040–1.735)	0.024	–	–
	Divorced/widowed	2.256 (0.745–6.831)	0.150	–	–
	Education level				
	High school or below	Ref		Ref	
	Bachelor's degree	0.873 (0.663–1.151)	0.336	0.953 (0.710–1.279)	0.749
	Master's degree or above	0.562 (0.352–0.896)	0.016*	0.654 (0.401–1.066)	0.088
	Other respiratory system diseases				
	No	Ref		Ref	
	Yes	4.926 (1.326–18.306)	0.017*	3.990 (1.026–15.515)	0.046*
	Hypertension				
	No	Ref		Ref	
	Yes	2.888 (1.201–6.947)	0.018*	2.519 (1.005–6.316)	0.049*
	Obesity				
	No	Ref		Ref	
	Yes	2.646 (1.189–5.889)	0.017*	2.711 (1.175–6.254)	0.019*
	SHS exposure				
	Smoker	Ref		Ref	
	Smoking inside home	0.908 (0.654–1.260)	0.562	0.861 (0.612–1.209)	0.387
	Vaping inside home	1.090 (0.413–2.876)	0.861	1.214 (0.448–3.289)	0.704
	Smoking at workplace	0.753 (0.540–1.052)	0.097	0.747 (0.529–1.054)	0.097
	Vaping at workplace	1.012 (0.585–1.751)	0.965	1.109 (0.629–1.955)	0.721
	No exposure	0.441 (0.304–0.639)	0.000*	0.443 (0.301–0.651)	0.000*
	Previous history of oral diseases				
	Neither	Ref		Ref	
	Both	0.690 (0.202–2.291)	0.534	0.442 (0.124–1.580)	0.209
	Only periodontal diseases	0.717 (0.484–1.061)	0.096	0.639 (0.425–0.960)	0.031*
	Only oral mucosal diseases	2.407 (1.190–4.869)	0.015*	2.150 (1.040–4.448)	0.039*
	Not known	0.660 (0.499–0.872)	0.003*	0.663 (0.496–0.886)	0.006*

Table 4. Logistic regression analysis showing oral health care, smoking habits, and self-reported oral manifestations of SARS-CoV-2 patients during the Omicron outbreak (N = 1053). SHS exposure, secondhand smoke exposure; AOR, adjusted odds ratio; CI, confidence interval; *represents statistical significance.

users reported taste disorders[53]. However, our adult-focused research did not confirm the relationship between smoking and dry mouth or oral ulcers. It suggested that e-cigarette users may have a higher risk of halitosis than non-smokers due to e-cigarette aerosols altering oral microorganisms, elevating levels of periodontal inflammatory markers, and increasing periodontal disease risk[54,55]. The limitation here is that the confidence interval between e-cigarette use and halitosis was relatively wide, indicating a smaller subgroup size.

SHS exposure affects oral symptoms differently than active smoking and remains critical for Omicron-infected individuals. Nearly half of non-smokers faced SHS exposure, with home exposure (cigarettes) being the most common, followed by workplace exposure (cigarettes). This is mainly due to workplace smoking restrictions during the epidemic, which made households the main place for passive smoking[56,57]. SHS exposes non-smokers to the same carcinogens as active smoking[54,58]. While smoking-induced high ACE2 expression is controversially linked to COVID-19, research on SHS exposure and COVID-19 is sparse[58,59]. In terms of specific oral symptoms, smoking reduces taste sensitivity and raises taste thresholds[58], explaining why non-smokers (without SHS exposure) had a lower risk of dysgeusia than smokers. Mengfan Liu et al.[19] also found a correlation between smoking history and dysgeusia but did not compare outcomes with SHS-exposed groups. Our finding further indicated that patients exposed to SHS at workplace were less likely to develop oral ulcers after infection than smokers, which has not been revealed in other studies. We should be concerned that SHS exposure is no less important for the oral health of Omicron-infected individuals than active smoking.

This is the first study in the Chinese Mainland to discuss the associations between oral health care, oral disease therapy, smoking types, SHS exposure and oral manifestations from the perspective of oral hygiene and smoking status among Omicron-infected adults. However, there are still the following shortcomings. Firstly, as a cross-sectional study, it cannot explain the causal relationship between oral health care, smoking and oral manifestations of SARS-CoV-2 infected patients. Secondly, it was primarily restricted to Shaanxi Province and its surrounding areas, and it had low coverage of elderly patients and low representativeness of severe cases within the sample, all of which limited the generalizability of hospitalization cohorts. Thirdly, although there was a positive correlation between clinical assessment and self-reported oral conditions[60], there has been an increase in recall bias due to self-reported data. Furthermore, a small number of infected individuals in this study had suffered from oral diseases, meaning oral symptoms may not be directly caused by SARS-CoV-2 infection.

Conclusions

The study investigated oral manifestations in Omicron-infected adults in Chinese Mainland and identified significant correlations between these manifestations and oral health care behaviors, as well as smoking status. These findings demonstrate that targeted measures might be needed: first, increase investment in oral health promotion to advocate for the public to maintain good oral care habits and seek timely treatment for pre-existing oral diseases; second, incorporate the control of SHS exposure and e-cigarette use into smoking cessation policies, which can help address oral damage caused by COVID-19. Due to the limitations of its cross-sectional design and self-report data, it is necessary to conduct large-scale longitudinal studies in the future to further explore causal relationships. Subsequent studies could focus on the impact of the severity of SARS-CoV-2 infection on oral manifestations, to provide a more comprehensive understanding of the interplay of COVID-19 with oral health.

Data availability

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

Received: 8 April 2025; Accepted: 25 September 2025
Published online: 31 October 2025

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Acknowledgements

We would like to appreciate all the participants in this study.

Author contributions

Conceptualization and design, HZ and RL; Investigation, HZ, ZXZ, LXL, XYW, RX, XRT; Data curation, HZ, LF,

YJZ; Formal analysis, HZ and YXW; Writing-Original draft preparation, HZ; Writing-Review & Editing, RL. All authors read and approved the final manuscript for submission.

Declarations

Competing interests
The authors declare no competing interests.

Ethical approval and consent to participate
The study was approved by the Ethics Committee of the Third Affiliated Hospital of the Air Force Medical University, the study was exempted from ethical review. All the procedures were conducted in accordance with the Declaration of Helsinki and related norms. Informed consent was obtained from all participants included before beginning the survey.

Consent for publication
Not applicable.

Additional information
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