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ORIGINAL RESEARCH

Imbalanced salivary electrolytes, COVID-19 severity, and dysgeusia

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Abstract

Early studies of patients who progressed to severe coronavirus disease 2019 (COVID-19) reported various serum electrolyte disturbances. Hyposalivation and dysgeusia are two of the severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) infection oral symptoms. This study investigated how SARS-CoV-2 infection affects saliva volume, pH, zinc, and inorganic components (sodium, potassium, calcium). The association between these salivary properties and dysgeusia was also investigated in patients with mild and severe COVID-19. Saliva volume, pH, zinc, sodium, potassium, and calcium were measured in 142 healthy persons (control) and 158 COVID-19 patients (72 mild and 86 severe). This study showed that saliva volume, pH, zinc, sodium, potassium, and calcium levels reduced dramatically during COVID-19. Likewise, these saliva characteristics were significantly lower in severe COVID-19 individuals than in mild COVID-19 cases. In addition, there was no correlation between dysgeusia and salivary composition, volume, or pH. All salivary indicators were reduced in the COVID-19 group reporting the loss of taste and smell and the group who perceived neither. These data suggested that COVID-19 is associated with many salivary abnormalities, including hyposalivation, decreased pH, and electrolyte imbalances. These were more pronounced in severe COVID-19 cases. According to the current study, saliva characteristics could be utilized for early diagnosis, quarantine, and therapy in COVID-19 patients. As a result, the virus transmission can be stopped, and the optimum therapeutic results might be obtained. COVID-19-associated dysgeusia was unrelated to the reduction of these changes.

Keywords

COVID-19; Saliva; Electrolytes; Dysgeusia; Zinc; pH; Volume; Severity

1. Introduction

The severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) originally arose in late 2019 in Wuhan, China. It has since evolved into a global phenomenon, producing coronavirus disease 2019 (COVID-19) [1]. Globally, as of 23 December 2022, there have been 651,918,402 confirmed cases of COVID-19, including 6,656,601 deaths, reported to WHO [2]. According to their prevalence among the Arab community, the most prominent symptoms of COVID-19 are headache, fever, generalized weakness, bone ache, gastrointestinal (GI) disturbance, myalgia, dyspnea, sweating, loss of taste and smell, sneezing, and runny nose [3]. The SARS-CoV-2 virus

is an enveloped RNA virus (order Nidovirales, family Coronaviridae, and sub-family Orthocoronavirinae). The virus is approximately 125 nm in diameter and is enveloped with spikes (glycoproteins) of nearly 9 to 12 nm, creating the virus' coronal form [4]. Coronavirus enters the host cells *via* its spike protein. The spike protein binds to the angiotensin-converting enzyme 2 receptors (ACE2R) through a receptor-binding domain (RBD), which is activated by transmembrane protease serine 2 (TMPRSS2). ACE2R and TMPRSS2 are expressed on the human tongue and gingival epithelial cells and are mainly concentrated in the dorsal language and the taste buds of the fungiform papilla [5, 6]. The expression of ACE2R and TMPRSS2 on the submandibular, parotid, and other salivary gland cell membranes indicates that salivary glands will be viable for coronavirus storage [7–9]. SARS-CoV-2 has been regularly found in the saliva of COVID-19 patients with high virus burdens [10, 11]. Regarding the known expression of ACE2R and TMPRSS2 on taste cells and salivary glands, coronavirus infection has been postulated to affect taste function and salivary secretion [12, 13].

The oral cavity, which is vulnerable to SARS-CoV-2, is thought to be a plausible location of human-to-human viral transmission and a source of COVID-19 oral manifestations [14–16]. COVID-19 patients have encountered a variety of oral symptoms, including decreased salivation (hyposalivation) and altered taste (dysgeusia). In some reports, oral ulcers and blisters are associated with SARS-CoV-2 infection [12]. Dysgeusia (including ageusia and hypogeusia) is a symptom of COVID-19 infection that appears early. 71% to 88.8% of COVID-19 patients experience taste disturbances [14]. A recent European multicenter epidemiological investigation examining the incidence of loss of taste and smell in a sample of 417 patients with verified positive coronavirus documented that 88.8% of patients had taste and olfactory impairments [17]. A cross-sectional online study found that of 59 patients who were positive for coronavirus infection, 71% reported loss or disturbances in taste [18]. A meta-analysis of 9 studies from Europe, North America, China, and the Middle East found taste disturbances in 43.93% of individuals infected with the coronavirus [19]. According to our recently published survey, COVID-19 patients in the Arab region have a 32% prevalence of loss of taste and smell [3].

Saliva and its contents are essential in the chemosensory perception of taste in the mouth. Zinc deficiency is linked with hyposalivation and taste changes [20]. Zinc insufficiency is one of the probable explanations for taste impairment linked to COVID-19. Low serum zinc levels can promote the worsening of sweetness, saltiness, and bitterness, consistent with the taste disorders observed in patients infected with the coronavirus [21]. Zinc is often necessary for immunity and inflammation, but this metal is also essential in gustatory function. It is crucial for the renewal and preservation of taste cells, and also, zinc-metalloenzymes are found in taste buds [22, 23].

Changes in saliva volume may be associated with taste abnormalities in COVID-19 patients, as saliva acts as a solvent for taste chemicals and regulates the state of taste receptors [24]. The decline in saliva flow may affect the release of antimicrobial proteins and peptides that demonstrate antiviral action, notably toward coronaviruses, and predispose individuals to an increased risk of developing COVID-19 [25]. Hyposalivation, most commonly associated with medication side effects, head and neck cancer radiation, and Sjögren's disease [26], can even be induced by viral and inflammatory diseases. As a result, coronavirus invasion of the salivary glands could disrupt saliva output [24]. The sweet and sour taste is not affected by the decrease in saliva volume, but a persistent sensation of bitterness and astringency is perceived [27]. The saliva flow rate and its inorganic contents, protein concentrations, particular 3′,5′-cyclic adenosine monophosphate (3′,5′-cAMP) and 3′,5′-cyclic guanosine monophosphate (3′,5′-cGMP) levels, ghrelin, pH levels, and enzymes all play a role in the chemosensory perception of tasting [28].

This study aimed to investigate the effects of coronavirus infection on saliva volume, pH, zinc, and inorganic components (sodium, potassium, calcium) compared to healthy saliva features. In addition, the association between these salivary properties and COVID-19 disease severity was assessed. Furthermore, the association between salivary volume, pH, and inorganic components (sodium, potassium, calcium) and dysgeusia was assessed in mild and severe COVID-19 patients.

2. Methods

2.1 Participants

The Saudi Arabian Ministry of Health (MOH) approved this research (A00981). This study included 142 healthy subjects (control) and 158 COVID-19 patients. The COVID-19 patients were separated into two groups: mild cases (86 patients) and severe cases (72 patients), according to the MOH classification guidelines, based on whether they only needed supportive measures (mild) or monitoring and/or intervention in the intensive care unit (ICU) (severe). Mild COVID-19 cases were collected from quarantine units in Jeddah, Saudi Arabia. Severe COVID-19 cases were gathered from several local Saudi government medical hospitals in Jeddah, Saudi Arabia. For all individuals, written informed consent was obtained before entering the study. The study period was between 01 September 2020 and 01 September 2021.

2.2 Sample size

The number of subjects was estimated using the mean and standard deviation of zinc in healthy and SARS-CoV-2-infected patients and a power of 80% at a 5% level of significance. The website ClinCalc.com was used to do the calculation (https://clincalc.com/stats/samplesize.aspx) [29].

2.3 Inclusion criteria

All of the volunteers in the study were unvaccinated against corona. In addition, participants in the control group did not currently or previously diagnosed with COVID-19. Negative polymerase chain reaction (PCR) findings confirmed control participants. Positive PCR findings confirmed COVID-19 cases. Swabs from the nasopharyngeal or oropharyngeal cavities were used in the PCR (MOH laboratory in Jeddah).

2.4 Exclusion criteria

Participants who had had a coronavirus vaccine, were under 18, or had autoimmune illnesses, periodontitis, oral mucosal disorders, or oral cancer were excluded.

2.5 Collection of sociodemographic data

All volunteers' sociodemographic data, such as nationality, age, gender, weight, height, and educational level, were obtained *via* a SurveyMonkey questionnaire delivered to each volunteer's WhatsApp number.

2.6 Collection of saliva samples

Methods of whole saliva collection include draining method, spitting method, suction method and swab method [30]. Among them, draining and spitting methods by dripping saliva off the lower lip or spitting the saliva from the floor of the mouth are reproducible and reliable for unstimulated whole saliva collection [31]. We used the spitting test to measure the unstimulated saliva secretion. Before the saliva collection, all participants were requested to fast, refrain from smoking, and stop oral hygiene for at least one hour. Saliva samples were collected between 7 and 9 AM using a passive drooling process following pre-determined guidelines [32, 33]. Whole unstimulated saliva was collected. The specimens were frozen at −20 °C and stored at −80 °C. The saliva samples were centrifuged for 10 mins at 3000 rpm and 4 °C to separate insoluble particles and cell debris. The supernatants were utilized in all of the tests.

2.7 Measurement of saliva pH

Saliva pH was measured using a single-electrode digital pH meter (CLEAN PH500 pH/mV Meter; Shanghai ZhenMai Instruments Co., Ltd, Shanghai, China).

2.8 Measurement of salivary concentrations of zinc, sodium, potassium, and calcium

Saliva contents of zinc, sodium (Na^+), potassium (K^+), and calcium (Ca^{++}) were quantified using the kits of MyBioSource (MyBioSource, Inc.; San Diego, CA, USA) according to the manufacturer's recommendations.

2.9 Statistical analysis

Descriptive statistics were performed concerning demographic and baseline clinical data, and data were expressed as frequency and percentage. Chi-square and Fisher's exact tests compared the demographic and clinical data. The normality of the distributions was evaluated using the Kolmogorov-Smirnov normality test concerning saliva volume, pH, zinc, sodium, potassium, and calcium measurements. The one way analysis of variance (ANOVA) test was used to compare the results of K^+ and Ca^{++} of all groups, followed by Tukey's multiple comparisons test. The Kruskal-Wallis test was used to compare the volume, pH, zinc, and Na^+ of all groups, followed by Dunn's multiple comparisons test. Finally, the unpaired *t*-test was used to compare the data of the COVID-19 group who lost taste and smell compared to the COVID-19 group that did not lose them. Statistical data analysis was performed using Prism® version 8.4.0 (GraphPad Software Inc.; La Jolla, CA, USA). The level of significance was established at $p < 0.05$.

3. Results

3.1 Sociodemographic characteristics of the study groups

The study included 142 participants in the control group and 158 in the COVID-19 group. Of the COVID-19 group, 72 (45.6%) patients were in the mild COVID-19 group, and 86 (54.4%) patients were in the severe COVID-19 group. Saudi persons constituted most of the control group (79.6%). Concerning age, body mass index (BMI), and educational levels, there was no significant difference between the control and COVID-19 groups. However, compared to the control group, there was a significant increase in males (74.1%) in the COVID-19 group ($p < 0.001$). There was no significant difference between the mild COVID-19 group and the severe COVID-19 group in terms of age or educational level. However, compared to the mild COVID-19 group, there was a significant increase in patients aged 40 years and more (84.9%), male (87.2%), and obese (46.5%) in the severe COVID-19 group ($p < 0.001$) (Table 1).

3.2 Differences in saliva volume between the control, mild COVID-19, and severe COVID-19 groups

The Kruskal-Wallis test revealed that, concerning the saliva volume, there was a statistically significant difference between the control, mild COVID-19, and severe COVID-19 groups ($p < 0.001$). Dunn's multiple comparison test revealed that saliva volume was statistically significantly decreased ($p < 0.001$) in the mild COVID-19 group (3.93 ± 0.07) and severe COVID-19 group (2.73 ± 0.11) compared to the control group (3.25 ± 0.11). Dunn's multiple comparison test also revealed that saliva volume was statistically significantly decreased in the severe COVID-19 group compared to the mild COVID-19 group ($p < 0.05$) (Fig. 1a).

An unpaired *t*-test found no significant difference in saliva volume between the COVID-19 groups with and without loss of taste and smell (Fig. 1b).

Dunn's multiple comparison test found no significant difference in saliva volume between the mild COVID-19 groups with and without loss of taste and smell. Also, there was no significant difference in saliva volume between the severe COVID-19 group with loss of taste and smell and the severe COVID-19 group without loss of taste and smell (Fig. 1c).

3.3 Differences in saliva pH between the control, mild COVID-19, and severe COVID-19 groups

The Kruskal-Wallis test revealed that, concerning the saliva pH, there was a statistically significant difference between the control and severe COVID-19 groups ($p < 0.001$). Dunn's multiple comparison test revealed that saliva pH was statistically significantly decreased ($p < 0.001$) in the severe COVID-

TABLE 1. Sociodemographic characteristics of the study groups.

Variables	Control (142)	All COVID-19 (158)	*p*-value	Mild COVID-19 (72)	Severe COVID-19 (86)	*p*-value
	Frequency (%)	Frequency (%)		Frequency (%)	Frequency (%)	
Age (year)						
Less than 40	78 (54.9%)	66 (41.8%)	0.2818	53 (73.6%)	13 (15.1%)	<0.001
40 and more	64 (45.1%)	92 (58.2%)		19 (26.4%)	73 (84.9%)	
Gender						
Male	66 (46.5%)	117 (74.1%)	<0.001	42 (58.3%)	75 (87.2%)	<0.001
Female	76 (53.5%)	44 (27.8%)		30 (41.7%)	11 (12.8%)	
Nationality						
Saudi	113 (79.6%)	87 (55.1%)	<0.001	43 (59.7%)	44 (51.2%)	0.3359
Non-Saudi	29 (20.4%)	71 (44.9%)		29 (40.3%)	42 (48.9%)	
BMI						
Normal weight	45 (31.7%)	36 (22.8%)	0.0931	25 (34.7%)	11 (12.8%)	0.0025
Overweight	58 (40.8%)	62 (39.2%)		27 (37.5%)	35 (40.7%)	
Obese	39 (27.5%)	60 (38.0%)		20 (27.8%)	40 (46.5%)	
Educational Level						
High school or less	44 (31.0%)	63 (39.9%)	0.1086	25 (34.7%)	38 (44.2%)	0.2263
College graduated or above	98 (69.0%)	95 (60.1%)		47 (65.3%)	48 (55.8%)	

COVID-19: coronavirus disease 2019; BMI: Body mass index.

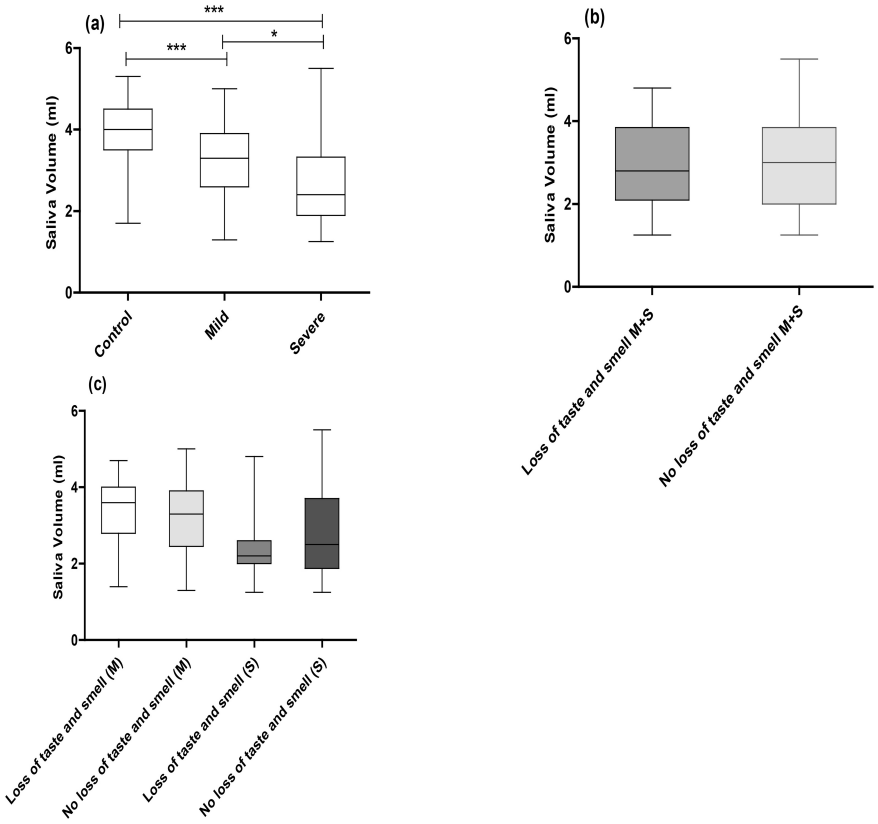

FIGURE 1. Box plots comparing saliva volume between the control, mild coronavirus disease 2019 (COVID-19), and severe COVID-19 groups. M: mild; S: severe; ***$p < 0.001$; *$p < 0.05$ (Dunn's multiple comparison test).

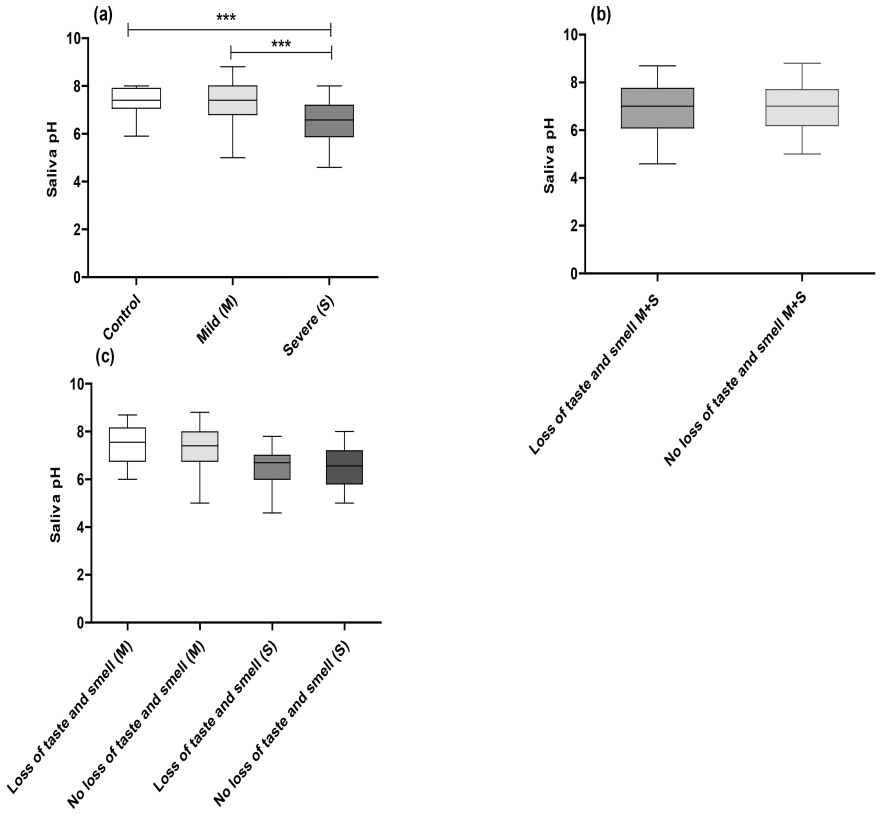

FIGURE 2. Box plots comparing saliva pH between the control, mild coronavirus disease 2019 (COVID-19), and severe COVID-19 groups. M: mild; S: severe; $^{***}p < 0.001$ (Dunn's multiple comparison test).

19 group (6.52 ± 0.09) compared to the mild COVID-19 group (7.29 ± 0.10). Dunn's multiple comparison test also revealed that saliva pH was statistically significantly decreased ($p < 0.001$) in the severe COVID-19 group (6.52 ± 0.09) compared to the control group (7.44 ± 0.04) (Fig. 2a).

An unpaired *t*-test found no significant difference in saliva pH between the COVID-19 groups with and without loss of taste and smell (Fig. 2b).

Dunn's multiple comparison test found no significant difference in saliva pH between the mild COVID-19 groups with and without loss of taste and smell. Also, there was no significant difference in saliva pH between the severe COVID-19 group with loss of taste and smell and the severe COVID-19 group without loss of taste and smell (Fig. 2c).

3.4 Differences in saliva zinc concentration between the control, mild COVID-19, and severe COVID-19 groups

The Kruskal-Wallis test revealed that, concerning the saliva zinc concentration, there was a statistically significant difference between the control and severe COVID-19 groups ($p < 0.001$). Dunn's multiple comparison test revealed that saliva zinc concentration was statistically significantly decreased ($p < 0.001$) in the severe COVID-19 group (0.29 ± 0.02) compared to the mild COVID-19 group (0.79 ± 0.02). Dunn's multiple comparison test also revealed that saliva zinc concentration was statistically significantly decreased ($p < 0.001$) in the severe COVID-19 group (0.29 ± 0.02) compared to the control group (0.97 ± 0.03) (Fig. 3a).

An unpaired *t*-test found no significant difference in saliva zinc concentration between the COVID-19 groups with and without loss of taste and smell (Fig. 3b).

Dunn's multiple comparison test found no significant difference in saliva zinc concentration between the mild COVID-19 groups with and without loss of taste and smell. Also, there was no significant difference in saliva zinc concentration between the severe COVID-19 group with loss of taste and smell and the severe COVID-19 group without loss of taste and smell (Fig. 3c).

3.5 Differences in saliva Na^+ concentration between the control, mild COVID-19, and severe COVID-19 groups

The Kruskal-Wallis test revealed that, concerning the saliva Na^+ concentration, there was a statistically significant difference between the control, mild COVID-19, and severe COVID-19 groups ($p < 0.001$). Dunn's multiple comparison test revealed that saliva Na^+ concentration was statistically significantly decreased ($p < 0.001$) in the mild COVID-19 group (131.9 ± 1.41) and the severe COVID-19 group (118.1 ± 0.95) compared to the control group (139.8 ± 0.49). Dunn's multiple comparison test also revealed that saliva Na^+ concentration was statistically significantly decreased in the severe COVID-19 group compared to the mild COVID-19 group ($p < 0.001$) (Fig. 4a).

An unpaired *t*-test found no significant difference in saliva Na^+ concentration between the COVID-19 groups with and without loss of taste and smell (Fig. 4b).

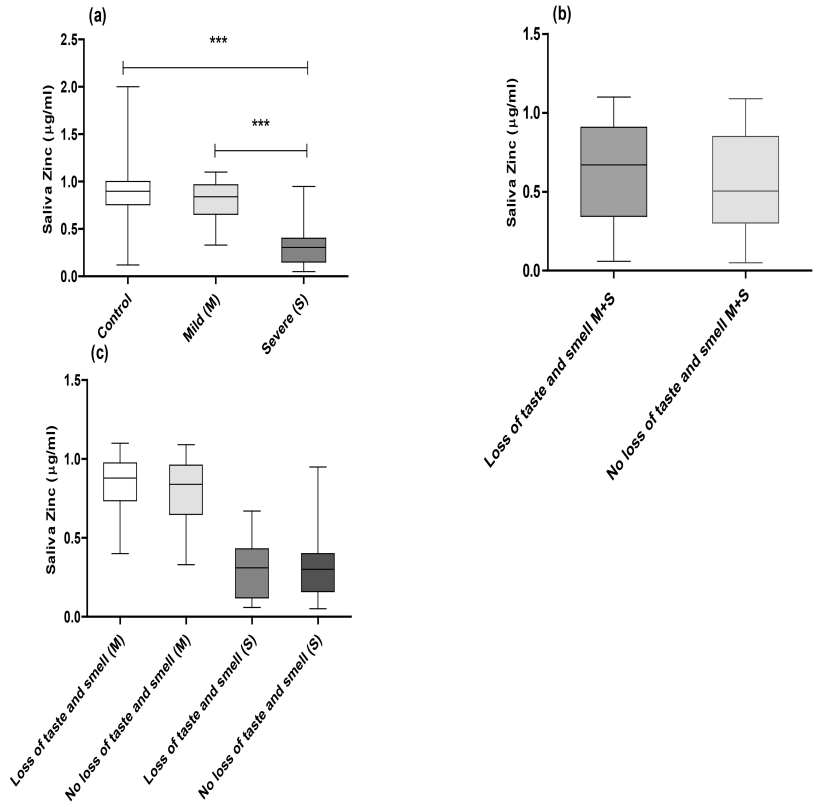

FIGURE 3. Box plots comparing saliva zinc concentration between the control, mild coronavirus disease 2019 (COVID-19), and severe COVID-19 groups. M: mild; S: severe; ***$p < 0.001$ (Dunn's multiple comparison test).

Dunn's multiple comparison test found no significant difference in saliva Na^+ concentration between the mild COVID-19 groups with and without loss of taste and smell. Also, there was no significant difference in saliva Na^+ concentration between the severe COVID-19 group with loss of taste and smell and the severe COVID-19 group without loss of taste and smell (Fig. 4c).

3.6 Differences in saliva K^+ concentration between the control, mild COVID-19, and severe COVID-19 groups

The ANOVA test revealed that, concerning the saliva K^+ concentration, there was a statistically significant difference between the control and severe COVID-19 groups ($p < 0.001$). Tukey's multiple comparison test revealed that saliva K^+ concentration was statistically significantly decreased ($p < 0.01$) in the severe COVID-19 group (3.49 ± 0.15) compared to the mild COVID-19 group (4.04 ± 0.18). Tukey's multiple comparison test also revealed that saliva K^+ concentration was statistically significantly decreased ($p < 0.001$) in the severe COVID-19 group (3.49 ± 0.15) compared to the control group (4.02 ± 0.06) (Fig. 5a).

An unpaired *t*-test found no significant difference in saliva K^+ concentration between the COVID-19 groups with and without loss of taste and smell (Fig. 5b).

Tukey's multiple comparison test found no significant difference in saliva K^+ concentration between the mild COVID-19 groups with and without loss of taste and smell. Also, there was no significant difference in saliva K^+ concentration between the severe COVID-19 group with loss of taste and smell and the severe COVID-19 group without loss of taste and smell (Fig. 5c).

3.7 Differences in saliva Ca^{++} concentration between the control, mild COVID-19, and severe COVID-19 groups

The ANOVA test revealed that, concerning the saliva Ca^{++} concentration, there was a statistically significant difference between the control, mild COVID-19, and severe COVID-19 groups ($p < 0.001$). Tukey's multiple comparison test revealed that saliva Ca^{++} concentration was statistically significantly decreased ($p < 0.001$) in the mild COVID-19 group (7.28 ± 0.13) and severe COVID-19 group (3.68 ± 0.15) compared to the control group (8.43 ± 0.07). Tukey's multiple comparison test also revealed that saliva Ca^{++} concentration was statistically significantly decreased in the severe COVID-19 group compared to the mild COVID-19 group ($p < 0.001$) (Fig. 6a).

An unpaired *t*-test found no significant difference in saliva Ca^{++} concentration between the COVID-19 groups with and without loss of taste and smell (Fig. 6b).

Tukey's multiple comparison test found no significant difference in saliva Ca^{++} concentration between the mild COVID-19 groups with and without loss of taste and smell. Also, there was no significant difference in saliva Ca^{++} concentration between the severe COVID-19 group with loss of taste and smell and the severe COVID-19 group without loss of taste and smell (Fig. 6c).

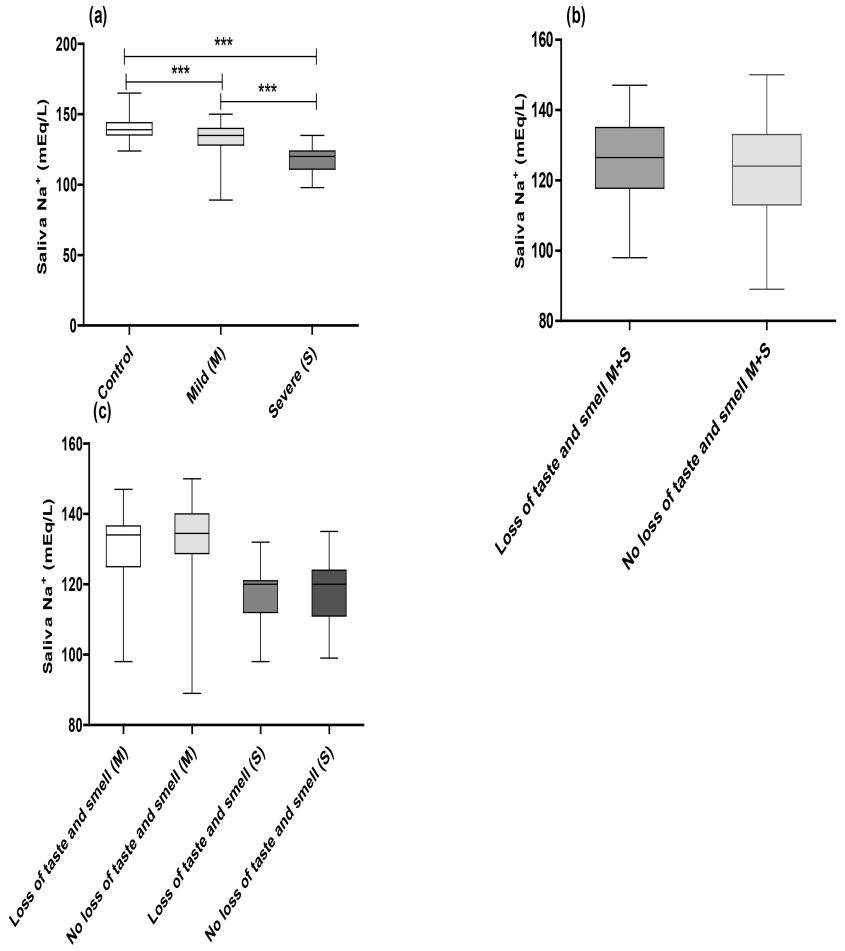

FIGURE 4. Box plots comparing saliva Na^+ concentration between the control, mild coronavirus disease 2019 (COVID-19), and severe COVID-19 groups. M: mild; S: severe; $^{***}p < 0.001$ (Dunn's multiple comparison test).

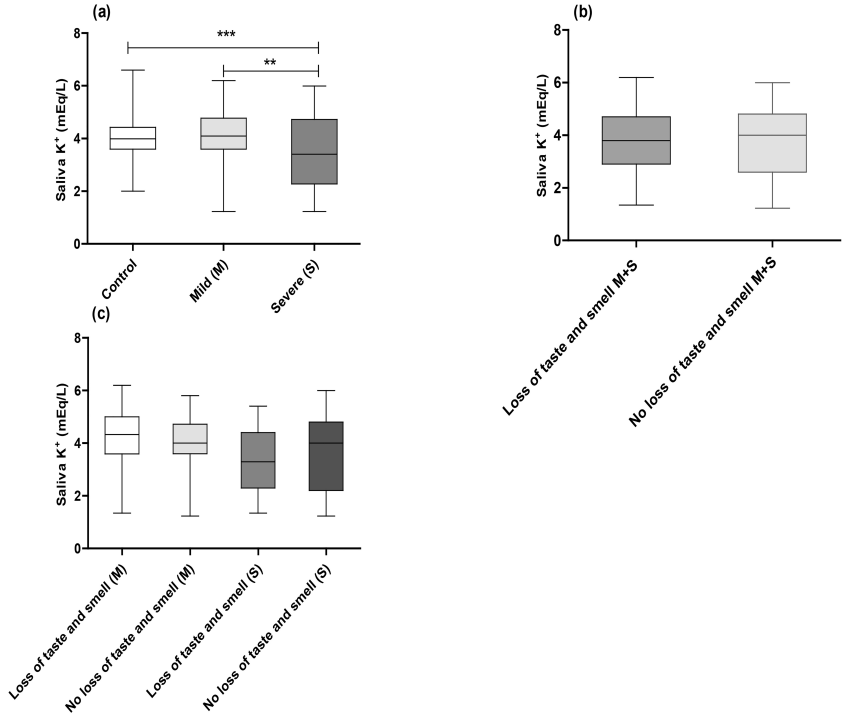

FIGURE 5. Box plots comparing saliva K^+ concentration between the control, mild coronavirus disease 2019 (COVID-19), and severe COVID-19 groups. M: mild; S: severe; $^{***}p < 0.001$, $^{**}p < 0.01$ (Tukey's multiple comparison test).

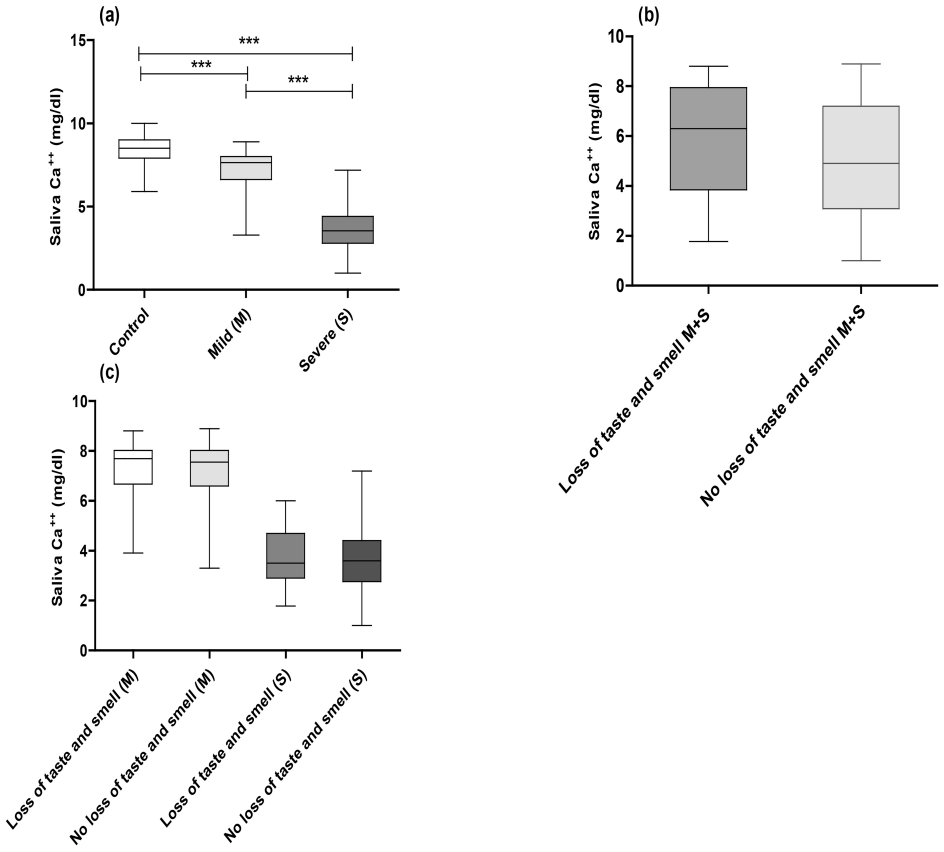

FIGURE 6. Box plots comparing saliva Ca^{++} concentration between the control, mild coronavirus disease 2019 (COVID-19), and severe COVID-19 groups. M: mild; S: severe; ***$p < 0.001$ (Tukey's multiple comparison test).

4. Discussion

The oral cavity can be affected by various viral illnesses, either directly or indirectly, resulting from systemic disorders. Furthermore, viral infections can present with multiple oral symptoms, the most common of which are ulcers or blisters of oral tissue [34–36]. Xerostomia (dry mouth) is present in many COVID-19 patients [10, 37]. Xerostomia is a disorder that occurs due to insufficient saliva secretion or absolute salivary gland dysfunction. Drugs are the most common cause of dry mouth. Type 1 diabetes, hyperthyroidism, renal failure, vitamin deficiencies, and some acute or chronic viral infections such as mumps, human immunodeficiency virus (HIV), and cytomegalovirus (CMV) are some of the other causes of dry mouth [37]. According to a recent publication, decreased saliva production puts patients at risk of developing COVID-19 as the availability of many antiviral proteins in the saliva is depleted [25]. COVID-19 is more severe in patients above 50 years old and in those with comorbidities such as cardiovascular illness, diabetes, and nervous system ailments [38, 39].

It has been postulated that coronavirus infection in salivary glands could produce changes in saliva content and flow, either directly or indirectly [40]. Salivary glands in rhesus macaques have been demonstrated to be an early target for SARS-CoV-2, and SARS-CoV RNA has been demonstrated to be present in saliva before pulmonary lesions [41]. According to the literature, the neuropathic and mucotropic effects of this virus can potentially affect the function of salivary glands and lead to hyposalivation and xerostomia [42]. As a result, the possibility of quantitative and qualitative salivary disorders due to SARS-CoV-2 infection in the salivary gland should be taken into consideration [12]. According to the findings of this study, saliva volume, pH, zinc, Na^+, K^+, and Ca^{++} levels all reduced dramatically during COVID-19. Likewise, these saliva characteristics were significantly lower in severe COVID-19 individuals than in mild COVID-19 cases. Hyposalivation can also be caused by viral and inflammatory diseases [43, 44]. Infection and inflammation of the salivary glands, especially in the early phases of viral diseases, are prevalent, causing alterations in the salivary components. A pooled analysis of 1415 COVID-19 patients found that the severity of COVID-19 was associated with lower serum Na^+, K^+, and Ca^{++} levels, consistent with current salivary findings [45]. As a result, saliva can be used instead of serum to detect electrolyte imbalances associated with COVID-19. Acute respiratory distress syndrome and acute heart injury, typical COVID-19 sequelae, are exacerbated by decreased serum K^+, especially in patients with underlying lung or heart disease. SARS-CoV-2 interacts with its host receptor ACE2R and presumably lowers ACE2 production, resulting in elevated angiotensin II, which might cause increased potassium excretion by the kidneys, eventually leading to lower serum K^+. Gastrointestinal leakage may play a role in COVID-19-associated hypokalaemia, and other electrolyte imbalances since nausea and diarrhea have been reported in up to 3.9% and 34.0% of patients, respectively [46]. Psychological factors could influence salivary flow rate

and components; hence, COVID-19's psychological impacts on salivary gland secretion and taste disturbances should not be overlooked [24].

The current study showed that changes in saliva composition, volume, and pH do not significantly correlate with odor or taste loss. All indicators decreased in the group of patients who reported loss of taste and smell, as well as the group who perceived neither. The taste disorders reported in individuals with COVID-19 are only subjective, and it is unclear whether these individuals are experiencing true taste or flavor changes. The general perception of dysgeusia is that the coronavirus can directly invade the olfactory epithelium or other components of the peripheral gustatory system [24]. According to numerous studies, COVID-19-related dysgeusia is thought to be caused by direct inflammation of the oral cavity mucosa and harm to taste buds [47–49]. Inflammatory cytokines can play a role in dysgeusia by affecting the thermoregulatory center, thalamus, and, ultimately, taste and smell pathways [50].

The major drawback of the current study was the discrepancy in gender between the control group and the COVID-19 group.

5. Conclusion

Saliva volume, pH, and electrolyte components were significantly reduced in all COVID-19 cases. For severe COVID-19 patients, these markers were statistically significantly lower than in mild COVID-19 cases. Severe COVID-19 cases had lower saliva pH, volume, zinc, and potassium levels. Decreased saliva volume usually occurs just before the common symptoms of the disease. Saliva may one day be applied as a noninvasive diagnostic tool to gauge and forecast the severity of COVID-19. These early signs could be used in the future for early diagnosis, quarantine and therapy in COVID-19 patients. Thus, it may be possible to halt the spread of the virus and get the best therapeutic outcomes. Additionally, there was no significant association between saliva volume, pH, and mineral ingredients and the observed loss of taste and smell in COVID-19 patients. A prospective study comparing the electrolyte concentrations in serum and saliva for individuals with mild and severe COVID-19 is recommended.

AVAILABILITY OF DATA AND MATERIALS

The data are contained within this article.

AUTHOR CONTRIBUTIONS

HAA, SSA, SBK, LWA, MI, IRNE, HAA—Designed the Study. HAA, IRNE, MI, HAA, LWA—performed the research. NAES, MDF, IRNE—analyzed the data. HAA, SSA, NAES—wrote the manuscript. All authors read and approved the final manuscript.

ETHICS APPROVAL AND CONSENT TO PARTICIPATE

The Saudi Arabian Ministry of Health (MOH) approved this research (A00981). For all individuals, written informed consent was obtained before entering the study.

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CONFLICT OF INTEREST

The authors declare no conflict of interest.

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