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ORIGINAL ARTICLE

Taste disorders following cancer treatment: report of a case series

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Abstract

Purpose To present the findings of combined oral assessment and gustometry testing of a series of head and neck and hematologic malignancies in patients with self-reported taste change after cytotoxic therapies.

Methods Patients with acute myeloid leukemia (AML), multiple myeloma (MM), and head and neck cancer (HNC) were evaluated for taste function. Chemical gustometry was conducted assessing chemosensory qualities that included sweet, sour, salty, bitter, umami, and spicy. NCI Common Terminology Criteria for Adverse Events (CTCAE) 4.0 and the Scale of Subjective Total Taste Acuity (STTA) were used to describe taste symptoms. Saliva flow rates were measured to determine the presence of hyposalivation. Patients were provided treatment trials for taste dysfunction, including zinc supplements, or medications that included clonazepam, megestrol acetate, and the cannabinoid dronabinol.

Results According to STTA, hematology cases reported the incidence of grades 2 and 3 taste disturbances as 60% and 40%, respectively. For HNC patients, the incidence of grades 2 and 3 was 44% each. Gustometry tests confirmed dysgeusia in all patients evaluated. In the hematology group, 80% of patients exhibited a decrease in sweet taste perception, and no patients correctly identified umami taste. In the HNC group, most patients could not identify salt taste, 66% of patients reported "no sensation" with spicy taste, bitter taste was reduced in some, and increased or altered in others, while only one patient could identify umami taste. In the hematologic and HNC patient groups, 80% and 66% reported grade 2 dry mouth, respectively, according to CTCAE 4.0. After treatment for taste dysfunction, 71% of all patients in the present study reported improvements in taste function.

Conclusions Persisting dysgeusia in cancer survivors may be assessed by patient report and taste testing. The taste most affected in our patients was umami. Treatment trials with current interventions for dysgeusia appeared effective and should be considered in cancer survivors. Understanding taste and flavor function during and following cancer treatment is important in developing rational prospective preventive and interventional strategies.

Keywords Dysgeusia · Taste tasting · Chemotherapy · Radiotherapy

Introduction

Flavor is a complex sensorial symptom [1]. Flavor involves interactions of taste, touch, temperature, and olfaction and requires appropriate saliva production. Taste is perceived through specialized neuroepithelial cells organized as taste buds in the oral cavity and oropharynx with large numbers on the dorsal surface of the tongue [2].

Taste allows an individual to evaluate food as nutritious, toxic, or noxious and to derive satisfaction from the experience of food consumption. The ability to enjoy the flavor and texture of food is connected to emotions, and generally invokes a sense of pleasure or well-being [3, 4].

In humans, five primary taste qualities are described as salty, sweet, sour, bitter, and umami [3, 4]. The latter taste quality is a relatively new term for a taste described as savory or pleasant,

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which is mediated by the binding of L-glutamate to taste receptors [4]. Umami, sweet, and bitter taste are detected by G protein–linked membrane receptors, while salt and sour tastes are thought to be detected via membrane channels [5].

Taste disturbances are described in four main categories: hypogeusia (decreased sensitivity to taste modalities), ageusia (loss of taste), phantogeusia (phantom taste), and dysgeusia (taste confusion or altered taste). The latter is commonly used as a general term for any type of taste disorder.

Approximately 0.6% of the US population experiences some form of dysgeusia [6]. This dysgeusia may be caused by damage to the gustatory system, loss or distortion of olfactory function, systemic disease, a loss of salivary output, and/or local oropharyngeal conditions [4, 7]. Taste changes may also be associated with aging, and reduced gustatory function is relatively common among elderly patients [8].

Dysgeusia is one of the most commonly reported symptoms of cancer patients [1, 4, 9, 10]. Cytotoxicity and neurotoxicity of systemic medications and regional head and neck radiation therapy are the principal causes of dysguesia in oncology care [1, 4]. Chemotherapeutic agents and/or metabolites secreted in saliva and/or gingival crevice fluid may lead to taste disturbances by direct damage to taste receptors [4, 11]. Furthermore, these drugs may impair taste bud cells proliferation and repair in the oral cavity, which may underlie taste changes during cancer treatment [1, 3, 4].

Oncology patients commonly report loss of specific taste qualities [3] and often describe a chronic bitter or metallic taste that affects all ingested foods and liquids [12]. These changes have a negative effect on quality of life and may contribute to increased morbidity and mortality [13]. Taste changes are also linked to reduced treatment compliance [14], impaired immune function [13], altered food relationships [13], change in food rituals, and emotional distress and interference with daily life [1].

There is limited published literature that assesses taste function and oral findings in oncology patients. Furthermore, most publications are limited to subjective patient reports. We present here results of a study of a cohort of five hematologic malignancy and nine head and neck cancer patients sequentially evaluated, who reported taste changes with oral assessment and clinical taste testing. The purpose of this case series is to assess taste testing and saliva function in cancer patients and to evaluate current approaches to management of taste function that may inform design for future studies of taste function in oncology care.

Methods

Patients

Five adult patients with acute myeloid leukemia (AML) or multiple myeloma (MM) were included in the hematologic malignancy group. All AML patients were treated with hematopoietic stem cell transplantation (SCT). The MM patient was treated with bortezomib and zoledronic acid. Nine patients with head and neck cancer (HNC) were treated with a combination of radiation therapy (RT) and chemotherapy (platinum based, except for one patient with thyroid cancer treated with radioactive iodine (I^{131}, 200 mCi)) (RAI). All patients were provided treatment options for minimizing taste dysfunction.

Clinical procedures

Chemical Gustometry test

Chemical gustometry was conducted to assess the primary taste qualities of sweet, sour, salty, bitter, and umami by using a modified Henke test [15]. Two milliliter solutions corresponding to these five primary taste qualities were each applied by eye-dropper to the dorsal surface of the tongue. Patients were asked to rinse their mouth with 10 ml of distilled water and expectorate it out after each taste application. Drops of sucrose (300 mg/ml) were applied to the right and left sides of the tongue to access sweet taste. This process was repeated to identify salt taste (80 mg/ml NaCl), sour (0.3 mg/ml citric acid), bitter (0.006 g/ml quinine–HCl), and umami (50 mg/ml L-monosodium glutamate rinse—MSG) followed by a 10-ml distilled water rinse and expectorate between samples. Rapidly dissolving edible taste strips were also used to evaluate the spicy/pungent sensation of capsaicin [16]. These pre-prepared taste strips were applied to the tongue sequentially [15, 16], with a distilled water rinse between applications.

Patients selected a chemosensory response from a list with the following choices: “sweet,” “salty,” “sour,” “bitter,” “spicy,” and “tasty,” or “no taste.” Perceived taste quality was identified by selecting the correct responses: sweet for sucrose, salty for NaCl, sour for citric acid, bitter for quinine, spicy for capsaicin, and umami for MSG.

Patient reported taste function

To describe taste change symptoms and relevant chemotherapy toxicities, the NCI Common Terminology Criteria for Adverse Events (CTCAE) 4.0 and the Scale of Subjective Total Taste Acuity (STTA) were used. The CTCAE provides patient-reported scoring of perceived dry mouth as part of adverse event reporting; the STTA is a scoring tool to assess the acuity of taste, where zero reflects no change, and four represents almost complete loss of taste function [4].

Measurement of salivary flow rate

Unstimulated and stimulated salivary flow rates were measured. All participants were asked to abstain from drinking

beverages 30-min prior to saliva collection [17]. Patients were seen either midmorning or mid-afternoon, and the samples were collected at the same time of the day. During saliva collection, each patient was assessed while sitting in an upright position and instructed to swallow their saliva prior to the test. Patients were instructed to not swallow any saliva during the collection period [17]. Each participant drained saliva from their lower lip into a pre-weighed cup for 3 min. For stimulated samples, each patient was provided a pre-weighed piece of unflavored/unpowdered vinyl glove to chew for 3 min and collected saliva in a pre-weighed cup. At the end of collection, cups and saliva were weighed and saliva flow rate expressed as milligrams per minute [17]. Hyposalivation was defined as less than or equal to 0.1 mg/min unstimulated, and 0.5–0.7 mg/min stimulated salivary flow [18].

Clinical data collection included concurrent medications, presence of conditions implicated in taste function (liver or renal dysfunction, sinusitis, diabetes), and treatment-related toxicities (nausea, dry mouth, and oral mucositis). Patients were prescribed sialogogues and trials for taste management (e.g., cannabinoids, clonazepam, megestrol, zinc supplementation). Follow-up of patients to assess the interventions was conducted at a mean of 2.6 months (range 1–6 months).

All patients provided signed informed consent.

Results

Patient demographics and clinical characteristics

Clinical characteristics of the patients are shown in Table 1.

Patient reported taste function

All patients reported taste disturbances when evaluated. Using the STTA, the incidence of grade 2 taste disturbance was 60%, and grade 3 was 40% for hematologic patients. For HNC patients, the incidence of grade 2 taste disturbance was 44%, grade 3 was 44%, and one patient reported grade 1 taste disturbance (11%) (Table 2).

In the HNC group, four patients (44%) reported disturbance in smell function on the Smell Identification Test.

Gustometry test

Gustometry testing confirmed dysgeusia in all patients evaluated, as shown in Table 3.

In the hematology group ($n = 5$), 80% of patients reported a decrease in sweet taste perception. In HNC group ($n = 9$), four patients (44%) described no taste, three (33%) described "abnormal taste," and two (22%) described "moderate to severe reduction" in sweet taste.

In the hematologic group, two patients (40%) identified salt taste correctly, one reported moderate to severe increased taste perception, another reported mild reduced taste, and one showed abnormal taste describing bitter instead of salt. In the HNC group, most patients could not identify salt, and 66% reported no taste or abnormal taste, describing salt as "chemical" or "oily."

In the hematologic group, one patient identified sour correctly, two showed moderate to severe increased taste, one described abnormal taste (bitter and salty instead of sour), and one described reduced sour perception. In the HNC group, five patients (55%) were not able to recognize sour taste. The other four patients (44%) reported a mild to severe increase in sour taste.

Bitter taste was altered in most patients and reported normal in one patient in each group. Reduced taste or no taste of bitter was reported in 60% of hematology patients and increased in 20%. In HNC, altered bitter taste was reported in all patients: 33% increased and reduced or abnormal in 67%.

In the hematologic group, none of the patients could identify umami, with three patients (60%) describing abnormal taste (e.g., sour, nasty, salty, acid) and the other two (40%) could not identify any taste at all. In HNC group, only one patient (11%) could identify umami with moderate to severe reduced taste.

In the hematologic group, two patients (40%) correctly identified capsaicin as spicy, two others did not (describing no taste), and one described a mild increase in sensitivity to spicy taste. In the HNC group, 66% of patients reported no taste when tasting spicy.

Umami was the least accurately identified tastant as only one HNC patient was able to correctly identify the taste, and even in this case, taste perception was reduced.

Salivary flow rate

Subjective dry mouth in the hematologic patients was grade 1 in 20% and grade 2 in 80%. For the HNC patients, grade 2 was recorded in 66% and grade 1 in 33% (Table 4). No grade 3 dry mouth was reported in this cohort.

In the hematology patients, hyposalivation was observed in 80% of patients. In the HNC group, 67% of the patients had hyposalivation and 33% had normal salivation (Table 5).

Dysgeusia treatments

All HNC patients were prescribed drugs to increase salivary flow (Table 1). In the HNC group, seven patients (77%) were provided zinc supplements, two zinc and clonazepam, and another two zinc and megestrol. One patient was prescribed dronabinol. In the hematologic group, two (40%) were taking

Table 1 Patient demographics, clinical characteristics, and type of interventions

Patients demographics	Hematologic ($n = 5$); n (%)	Head and neck ($n = 9$); n (%)
Median age	62	69
Gender:		
Male	1 (20%)	5 (55%)
Female	4 (80%)	4 (44%)
Cancer diagnosis**:**		
Acute myeloid leukemia	3 (60%)	
Multiple myeloma	1 (20%)	
Acute lymphocytic leukemia	1 (20%)	
Squamous cell carcinoma		8 (88%)
Hurthle cell thyroid		1 (11%)
Time post treatment (months)	± 11	± 3
Treatment for cancer:		
Stem cell transplant	4 (80%)	
Chemotherapy	1 (20%)	8 (88%)
Radiotherapy		8 (88%)
RAI (radioactive iodine)		1 (11%)
Treatment for saliva/dry mouth:		
Bethanechol	1 (20%)	6 (66%)
Anetholetrithione		1 (11%)
Pilocarpine		4 (44%)
Chitosan-based oral rinse		1 (11%)
Cevimeline	1 (20%)	1 (11%)
Treatment for taste:		
Zinc supplement (3× RDA)	2 (40%)	7 (77%)
Clonazepam (0.5 mg—2×/day)	2 (40%)	2 (22%)
Dronabinol (2.5 mg—2×/day)	1 (20%)	1 (11%)
Megestrol acetate (40 mg—2×/day)	1 (20%)	2 (22%)
Mucositis/GVHD		
Photobiomodulation(PBM)	1 (20%)	3 (33%)

zinc supplements, one combined zinc with megestrol and dronabinol, and one zinc combined with clonazepam. One patient was prescribed clonazepam alone.

Four patients received low-level laser therapy (photobiomodulation therapy—PBMT). One patient from the hematologic group had PBMT for the treatment of oral

Table 2 Presence of taste alteration according to STTA

Taste alteration	Hematologic patients, n (%)	Head and neck patients, n (%)
Grade 0	0	0
Same taste acuity as before treatment.		
Grade 1	0	1 (11%)
Mild loss of taste acuity, but not inconvenient in daily life.		
Grade 2	3 (60%)	4 (44%)
Moderate loss of taste acuity, and sometimes inconvenient in daily life.		
Grade 3	2 (40%)	4 (44%)
Severe loss of taste acuity, and frequently inconvenient in daily life.		
Grade 4	0	0
Almost complete or complete loss of taste acuity.		

Table 3 Summary of gustatory testing

Hematologic patients ($n = 5$), n (%)								Head and neck patients ($n = 9$), n (%)						
Descriptors*	0	1	2a	2b	3a	3b	4	0	1	2a	2b	3a	3b	4
Tastants														
Sweet	1 (20)		4 (80)					4 (44)		1 (11)	1 (11)			3 (33)
Salt		2 (40)	1 (20)			1 (20)	1 (20)	4 (44)	1 (11)	1 (11)		1 (11)		2 (22)
Sour		1 (20)	1 (20)			2 (40)	1 (20)	2 (22)				3 (33)	1 (11)	3 (33)
Bitter	2 (40)	1 (20)	1 (20)		1 (20)			1 (11)		1 (11)	3 (33)		3 (33)	1 (11)
Umami	2 (40)						3 (60)	3 (33)			1 (11)			5 (55)
Spicy	2 (40)	2 (40)			1 (20)			6 (66)		2 (22)			1 (11)	

*Descriptors of identification of the tastants: 0 = no taste, 1 = normal taste, 2 = reduced taste (2a = mild reduced, 2b = moderate to severe reduced), 3 = increased taste (3a = mild increased, 3b = moderate do severe increased), 4 = abnormal taste

graft-versus-host disease. Three patients from the HNC group received PBMT for residual oral mucositis.

Follow-up appointments

Seventy-one percent of all patients in our study reported improvements in taste function after a number of interventions were provided.

The allo-SCT patient that was prescribed clonazepam reported improvement in taste. Among the hematology patients, all subjects reported improvement in dry mouth, oral burning symptoms, and mucositis between 1 and 2 months after initial assessment. One SCT patient had chronic graft-versus-host disease (GVHD) and reported that oral symptoms including taste improved with improvement of GVHD.

Among HNC patients, most reported improvement in taste after treatment, but all had continuing dry mouth (Table 6). One patient provided PBMT for mucositis and taste had complete recovery after 3 weeks of treatment. One patient prescribed megestrol for taste change reported no improvement. One HNC patient treated with both dronabinol and PBMT reported complete recovery of taste function after 2 months.

Discussion

Taste changes are a common side effect of SCT [19]. SCT patients in this study reported taste disturbances up to 1 year after transplantation. The same observation has been reported in other studies, where taste changes and dry mouth persist for long periods following SCT [20, 21]. Hull et al. [20] reported that 20% of allo-SCT patients reported taste reduction up to 6 years post-therapy. A Dutch study [21] described taste alterations in 61% of patients at day 50 post-transplant, with taste change persisting in 7% of subjects at 1 year post-transplant [21]. Boer et al. [22] evaluated 61 patients after allo-SCT and found taste alterations over an extended period post-transplantation. These results support the concept that these changes may not correlate directly with oral mucosal injury due to mucositis or chronic GVHD and/or changes in salivary function, as symptoms may also relate to conditioning regimen and concurrent medications [22].

Dysgeusia may differ between recipients of auto-SCT and allo-SCT [23]. Early taste disturbances after auto-SCT are thought to be largely due to direct conditioning regimen-related oral mucosal and salivary gland injury [22]. In our study, all hematologic malignancy patients were recipients of allo-SCT, for which dysgeusia may represent a longer-lasting

Table 4 Presence of mouth dryness according to CTCAE

Dry mouth	Hematologic patients, n (%)	Head and neck patients, n (%)
Grade 1	1 (20)	3 (33)
Symptomatic without significant dietary alteration; unstimulated saliva flow > 0.2 ml/min)		
Grade 2	4 (80)	6 (66)
Moderate symptoms; oral intake alterations; unstimulated saliva 0.1to 0.2 ml/min		
Grade 3	0	0
Inability to adequately aliment orally; unstimulated saliva < 0.1 ml/m		

Table 5 Resting and stimulated saliva flow rates

Patients	Whole resting salvia (mg/min)	Whole stimulated saliva (mg/min)
Hematologic patients		
1	0.15	0.33
2	0.09	0.51
3	0.13	033
4	0.0	0.25
5	1.14	2.12
Head and neck patients		
6	0.07	0.02
7	0.05	0.43
8	0.89	2.22
9	0.05	0.35
10	0.08 hypo	0.12
11	0.89	1.87
12	0.07	0.02
13	0.76	1.44
14	0.0	0.02

and more complex condition [24]. Possible explanations include more aggressive conditioning regimens, continued exposure to immunosuppressant medications, increased frequency of infections, and the use of total body irradiation (TBI)-based conditioning [25], as well as immune mechanisms of GVHD.

Saliva quantity and quality can influence taste sensation [1]. Hyposalivation may limit saliva food-coating resulting in decreasing food particle contact with taste receptors, resulting in diminished taste perception [17]. In our study, hyposalivation occurred in 80% of the hematologic patients who also reported that dry mouth was associated with oral intake alterations [10, 22, 24].

Most reports addressing taste function in cancer patients present only subjective data and identify sweet taste perception as reduced or abnormal in most patients. Boer's study showed that allo-SCT patients had difficulty perceiving taste intensity of high and low concentrations of sucrose (sweet). In our study, taste alterations were observed for both sweet and salty tastes up to 3 years after SCT. In a study of allo-SCT and auto-SCT patients, Marinone et al. [25] showed that most patients undergoing allo-SCT had a persistent alteration in salt and sour taste. In our study, most patients reported increased sensitivity or abnormal acidic (sour) taste in both HNC and hematologic patient groups. A prior study has shown that sour–bitter taste confusion is common [18].

The impact of radiation therapy on taste is multifactorial. Direct radiation exposure to the oral cavity, oropharynx, and larynx affect mucosal tissue that may lead to mucositis and damage to the taste receptors [1, 4]. Loss or distortion of olfactory function and local oropharyngeal conditions, particularly due to hyposalivation, may further influence flavor perception. Olfaction significantly contributes to the flavor of food via stimulation from volatile compounds that reach the olfactory epithelium [1, 14]. Olfactory deficits have been associated with antineoplastic agents, including cisplatin, doxorubicin, methotrexate, and vincristine [14]. In our report, three HNC patients (33%) reported smell disturbance coupled with taste disturbances. Of the patients that reported smell disturbances, two were seen approximately 3 to 4 months after treatment with combined radiation therapy and chemotherapy.

Patients with damage to the salivary glands caused by cancer therapy may report taste loss associated with hyposalivation [18, 24]. Taste change during radiation therapy is typically concurrent with mucosal damage suggesting damage to epithelial components of the taste receptors; persisting change in taste may reflect limited repair, damage to the neural tissue, or change in the oral environment. Nguyen and colleagues [2] found that irradiation causes loss of taste progenitor basal cells and interferes with cell proliferation, which together result in decreased replacement after physiological loss of taste buds within papillae [2, 26, 27]. While some patients who experience taste loss due to radiotherapy or chemotherapy may recover within a few months to a year after completion of cancer treatment [28], others may not fully recover their taste function for years and may eventually lose awareness of their taste dysfunction [28, 29].

Table 6 Change in taste alteration according to STTA before and after taste treatment

Taste alteration	Before	After	Before	After
	Hematologic patients		Head and neck patients	
Grade 0 Same taste acuity as before treatment	0	1 (20%)	0	1 (11%)
Grade 1 Mild loss of taste acuity, but not inconvenient in daily life	0	3 (60%)	1 (11%)	5 (55%)
Grade 2 Moderate loss of taste acuity, and sometimes inconvenient in daily life	3 (60%)	0	4 (44%)	2 (22%)
Grade 3 Severe loss of taste acuity, and frequently inconvenient in daily life	2 (40%)	1 (20%)	4 (44%)	1 (11%)
Grade 4 Almost complete or complete loss of taste acuity	0	0	0	0

All HNC patients described in this case series had moderate to severe taste disturbance and dry mouth. Some of patients them had normal saliva flow, including one who was treated for thyroid cancer and had received radioactive iodine; the other had completed RT treatment 1 year prior; nevertheless, both of these subjects were experiencing taste alterations. It has been reported that 75 to 100% of patients who have undergone head and neck RT experience taste abnormalities, depending on the radiation dose and treatment fields [4, 30, 31].

Gustometry showed that the five primary taste qualities were affected after cancer treatment. The HNC patients had a high number of reported no taste or abnormal taste. Yamashita showed a correlation between diminished sweet sensitivity and increase sour sensitivity [32]. The same correlation was noted in six patients in our report.

Bitter taste was altered in most patients. Reduced taste or no taste of bitter was reported in 60% of hematology patients and increased in 20% of HNC patients with variable changes of reduced or abnormal taste in two-thirds and increased intensity in one-third.

Umami taste perception was the most affected sensation with almost all patients describing no taste or abnormal taste upon taste testing. The only HNC patient that could describe umami had moderate to severe reduced taste at 6 months after radiation therapy. According to Shi [33], the clinical impairment pattern of umami taste is different from that of the other four primary tastes in HNC patients and plays an important role in impacting their quality of life. Loss of umami taste may be important in oral intake because this taste quality affects interest in eating (enjoyment, pleasure) and thus may have the strongest correlation with appetite and therefore oral intake and with decrease in quality of life [33]. Although this taste quality commonly declines during the third week of RT, some improvement is reported in some studies by the eighth week [32, 34]. However, recovery of umami taste in some cases may be delayed and may persist indefinitely [1, 19, 33]. The loss of umami taste may have profound impact and requires attention of the health care team.

Current approaches to taste management involve treatment strategies with a goal of reduced acute mucosal damage (mucositis), good oral hygiene, and addressing dental/oral disease and hyposalivation [19]. Current guidance for medical intervention in taste change is based on preliminary studies. Some studies report that zinc gluconate (50 mg, three times daily) had a positive effect on taste disorders in patients with idiopathic taste loss [35–37]. The potential mechanism for its effect is that zinc may promote proliferation of normal taste bud basal cells, even in patients without zinc deficiency [36]. Some studies have suggested that gamma-aminobutyric acid (GABA) plays a role in taste function [38–40]. Clonazepam, a GABA type A receptor agonist, may be helpful for treating phantom tastes and has been effective in treating taste alterations associated with burning mouth syndrome [39, 40]. Potential additional approaches for management of dysgeusia include treatment trials of megestrol and cannabinoids, which have limited evidence of benefit [1, 35].

Dronabinol, a synthetic cannabinoid used to treat loss of appetite, may also palliate chemosensory alterations to improve food enjoyment in cancer patients [41]. Taste studies show that cannabinoid receptor agonists increase the hedonic reactions to sweet taste and reduce the aversive reactions to quinine, resulting in increase in palatability [42]. A phase II randomized double-blind placebo-controlled pilot study with dronabinol showed effect in treatment of taste and smell alterations and increasing oral intake in adult patients with advanced cancer [41].

When hyposalivation is present, a therapeutic trial with a sialogogue is recommended. Continuing study of these potential approaches to medical management of dysgeusia is needed and requires dose-finding studies and placebo-controlled trials.

One allo-SCT patient had oral GVHD and taste change [22]. In addition to immune mechanisms, a common GVHD prophylaxis regimen with methotrexate may be an additional source of mucosal toxicity. The patient was treated with PBM for oral GVHD and experienced concurrent recovery of taste with improvement in GVHD. Another HNC patient with grade 3 mucositis had full recovery of mucositis and taste change after 2 weeks of PBM therapy (2×/week). There is a body of evidence supporting PBM for the management of oral mucositis in patients undergoing radiotherapy for HNC and in myeloablative SCT recipients [43, 44]. The potential benefits include reduction of inflammation and pain, promotion of tissue repair, reduction of fibrosis, and protection and regeneration of nerves [45], which may impact taste receptor and taste function.

Persisting dysgeusia is common in cancer survivors and affects quality of life beyond active cancer treatment [1, 3, 4]. Understanding taste and flavor function during and following treatment is important in developing rational prospective preventive and interventional strategies that can reduce the incidence and severity of this pervasive complication, including diet management. Future studies should include patient reported outcomes, taste and olfactory testing, evaluation of relevant oral/dental conditions, dietary assessment, nutritional evaluation, and quality of life. Finally, randomized interventional multicenter studies are needed.

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Compliance with ethical standards

Conflict of interest The authors declare that they have no conflict of interest. The authors have full control of all primary data and agree to allow the journal to review the data if requested.

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