The Saudi Dental Journal (2025) 37:41
https://doi.org/10.1007/s44445-025-00048-5

REVIEW

Perspectives on tongue coating: etiology, clinical management, and associated diseases — a narrative review

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Received: 7 May 2025 / Accepted: 29 July 2025

Abstract
Tongue coating (TC) is a biofilm comprising desquamated epithelial cells, food debris, and microorganisms. TC is commonly found across populations and may hold significant implications for both oral and systemic health. Factors such as age, diet, smoking, and systemic conditions influence its formation. TC is a primary reservoir for pathogenic bacteria and is closely linked to halitosis and periodontal disease. Beyond oral health, TC has been associated with systemic diseases, including aspiration pneumonia, cardiovascular disease, and diabetes, through mechanisms involving microbial translocation and low-grade inflammation. Literature search was performed using search engines and databases including, PubMed, Google Scholar, Web of Science and Medline, utilizing key words such as "Tongue coating," "Tongue cleaning," "Halitosis and Oral malodor". This review assesses the etiology, composition, and health implications of TC, highlighting its microbial diversity and correlation with oral and systemic conditions. Additionally, it examines interventions such as mechanical cleaning, chemical treatments, and dietary modifications to manage TC effectively. Emphasizing tongue hygiene as part of routine oral care is crucial for enhancing oral health, mitigating systemic risks, and improving quality of life.

Keywords Tongue coating · Tongue cleaning · Halitosis · Microbiome · Periodontal disease

1 Introduction

Tongue coatings are often seen in patients and are of interest, because they may reflect a patient's oral and/or systemic health. (Sedghi et al. 2000) A significant portion of the population (50 to 90%) at some time experience tongue coating to different degree. (Campisi and Margiotta 2001; Rana A et al. 2015) Most people have some coating on their tongues in the morning (i.e., a thin whitish layer) and this is considered normal. However, when it is thick or chronically present, it may reflect an oral or systemic variation of health or possibly a disease. Anatomically, the tongue with fissures, grooves and papillae provides an environment for debris and bacterial retention. (Abbate et al. 2012) Microbiologically, the dorsum of the tongue may manifest a higher bacterial load than other intraoral sites (Faveri et al. 2006), creating a reservoir associated with halitosis, periodontal diseases, caries and systemic issues. (Amou et al. 2014; Van Tornout et al. 2013) TC formation is influenced by factors such as rate of salivary flow, age, gender, dietary habits, smoking, and general health status. (Ogami et al. 2018; Van Gils et al. 2020) Despite its clinical relevance, TC evaluation is often overlooked in routine oral examinations. This review explores the impact of TC on oral and systemic health. It focuses on microbial composition, correlations with clinical findings, and interventions for disease prevention and management.

2 Mechanisms of tongue coating formation

TC can be caused by intraoral conditions (eg, leukoplakia, salivary flow reduction) (Seerangaiyan et al. 2018) or systemic diseases (eg, diabetes, gastritis). (Hsu et al. 2019; Yanan et al. 2022) Tongue coatings are primarily composed of desquamated epithelial cells, bacteria, blood metabolites, secretions from the postnasal region, and saliva. (Abbate et al. 2012) Oral mucus plays a crucial role in holding TC components together. Filiform papillae on the dorsal surface of the tongue play a central role in TC development

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Published online: 20 August 2025

by providing debris retentive areas. The tongue's surface is comprised of both keratinized and non-keratinized epithelial cells; there is usually an equilibrium between retention and cell shedding from these surfaces. (Seerangaiyan et al. 2018) A thickened and persistent tongue coating reflects a shift in this equilibrium. A decreased salivary flow nocturnally is a normal physiological event and is considered part of the body's circadian rhythm. Reduced salivary flow is associated with dry mouth at night or"xerostomia"and can be exacerbated by factors like mouth breathing, dehydration, or certain medications. All these factors can result in increased tongue coating and predispose a patient to fungi overgrowth especially in cases of immunosuppression or poor oral hygiene. (Tahmasebi et al. 2023).

3 Tongue coatings composition

3.1 Texture and size of TC

Before analyzing tongue coatings (TCs), recognize that factors such as the light source and patient position during examination can influence their appearance and color. (Murakami et al. 2024) Note, TCs are commonly found in healthy dental patients. A typical TC is characterized by a thin, slightly moist, whitish layer on the tongue's dorsal surface. However, its color, thickness, moisture level, and distribution may vary based on an individual's oral or systemic health. (Anastasi et al. 2009) TC is often assessed by the percentage of the covered tongue's surface, by visual inspection or by weight analysis (Table 1). (Chérel et al. 2008; Hartley et al. 1996; Kim et al. 2009; Shanbhog et al. 2023; Winkel et al. 2003) Reduced rate of epithelial desquamation may result in elongated filiform papillae and is referred to as hairy tongue. Initially, white hairy tongue in the presence of poor hygiene can become black hairy tongue. This latter condition may also be associated with smoking, antibiotics and dry mouth, creating an environment for bacterial and fungal overgrowth. (Gurvits and Tan 2014).

3.2 Microbial composition

Tongue microbial populations associated with intraoral and systemic conditions vary and are not easily differentiated by oral inspection. However, they do have some similar features. The tongue's dorsal surface is colonized by large amounts of bacteria and this niche can retain malodorous byproducts. (Faveri et al. 2006) A tongue with deep fissures harbors twice the number of bacteria compared to a smooth tongue. (De Boever and Loesche 1995) The tongue surface has a diverse microbiome, predominantly composed of bacteria such as *Streptococcus*, Actinomyces, *Veillonella*, and *Porphyromonas*, Neisseria, and Aggregatibacter. (He et al. 2022) Thinner coatings in healthy individuals are generally associated with a balanced microbial community dominated by commensal bacteria that contribute to oral homeostasis. In contrast, thicker or more pronounced coatings, even in healthy individuals, may exhibit higher bacterial loads, including anaerobic species capable of producing VSCs. (Ye et al. 2019) Various types of TCs are observed in healthy individuals. For instance, Chen et al. (2021) categorized the TCs of healthy participants into eight groups as follows: white thin, white thin greasy, white thick greasy, white thick dry, yellow thin, yellow thin greasy, yellow thick greasy, and yellow thick dry. They noted a slight difference in microbial composition of the tongue coating across these categories. (Chen et al. 2021) Similarly, He et al. (2022) reported that the microbial composition across different TCs among healthy adults was generally similar; however, variations were observed with respect to abundance of specific microorganisms. For instance, thin white tongue coatings exhibited higher levels of *Fusobacterium periodonticum* and *Neisseria mucosa* than tongues with a thin yellow coating. (He et al. 2022) An increased thickness of tongue coating

Table 1 Methods for quantifying and assessing tongue coating

Method	Advantages	Limitations
Visual Scoring (WTCI) (Winkel et al. 2003)	Quick, simple, and widely used	Subjective and lacks biochemical details
Photographic Analysis (Kim et al. 2009)	Objective and reproducible. Calculated from digital images obtained by the digital tongue imaging system (DTIS)	Requires controlled lighting and angles
Quantitative light-induced fluorescence (QLF) (Shanbhog et al. 2023)	It combines (QLF) with Digital Image Analysis (DIA) to assess the extent, thickness, and composition of the coating on the tongue's surface. objective, efficient, and often noninvasive	High cost and expertise required. Limited Depth Assessment
Wet/Dry Weight Analysis (Chérel et al. 2008)	Provides quantitative measurement of coating	Invasive and impractical for routine use
Microbial and Biochemical Tests (Hartley et al. 1996)	Highly specific for bacterial and biochemical ID	Expensive and time-consuming

*Winkel Tongue Coating Index (WTCI)

was associated with an amplified and diverse microbiota. Similarly, the TC manifested a significantly higher number of bacteria in individuals with halitosis. These TC manifested a substantial increase in the abundance *Actinomyces*, *Prevotella*, *Veillonella*, and *Solobacterium.* (Zhang et al. 2024) Bacteria associated with systemic diseases vary intraorally. For example, patients with the gastritis may manifest elevated levels of Bacillus which may be a marker for yellow tongue coating and Proteobacteria is elevated in yellow tongue coating in chronic hepatitis B patients. (Yanan et al. 2022) Syphilis (spirochetes) can cause a white tongue and helicobacter pylori infection can alter the composition of the tongue. (Irani 2017) The tongue dorsum serves as a primary habitat for bacteria associated with periodontal disease, and includes *P. gingivalis*, *T. denticola, and T. forsythia.* (Su et al. 2019) These microbes are strongly linked to the progression of periodontitis. They also play a role in the onset of halitosis by increasing the production of VSCs. (Kato et al. 2005; Takeuchi et al. 2017) In this regard, Amou et al. (2014) studied the correlation between halitosis and periodontal disease and reported that clinical indicators of halitosis were positively correlated with the levels of *P. intermedia*, *F. nucleatum*, and *C. rectus* found in TC samples. (Amou et al. 2014).

3.3 Methods for quantifying and assessing tongue coating

Assessing TC qualitatively and quantitatively is essential for understanding its role in oral and systemic health. Both approaches are employed to evaluate TC based on its extent, thickness, color, and composition. These methods are categorized into visual inspection, scoring systems, and advanced analytical techniques, each offering distinct advantages and limitations (Table 1).

3.4 Factors influence tongue coating

Numerous factors influence tongue coating formation; age, oral hygiene, salivary flow, intraoral and systemic conditions. Age can influence TC through physiological and lifestyle changes that affect oral health. For example, filiform papillae may contribute to TC formation, they were observed to increase in numbers with age, while fungiform papillae showed a reduced prevalence as age advanced. (Danser et al. 2003) Older adults often experience a thicker TC than younger people due to reduced salivary flow and higher bacterial loads found on the tongue. (Buranarom et al. 2020; Ralph 1988) Impaired oral hygiene can lead to bacterial and fungal accumulation. Lack of oral hygiene will usually result in creation of tongue coatings that increase over time and may result in malodor.

Chewing and salivary flow are major factors influencing tongue coating formation. They help cleanse the mouth while the patient is awake. During the night, salivary flow is decreased to almost zero. Throughout the day, the salivary flow is 0.3–0.4ml/min (unstimulated). (Iorgulescu 2009) Without salivary cleansing, the intraoral bacterial load increases especially on the tongue. Consequently, it is common to have a tongue coating upon awakening in the morning.

3.5 The role of diet in tongue coating accumulation

Tongue coating appearance varies based on foods consumed, ranging from a clear, watery layer to a thick, pigmented, and mucus-like substance. Fatty and greasy foods, particularly those high in fat content are known to promote TC formation. (Christensen 1998) Diets high in soft processed foods reduce the abrasive action of chewing, leading to greater biofilm buildup. Conversely, fibrous foods, such as fruits and vegetables, promote mechanical cleaning and stimulate saliva production. Sugary and carbohydrate-rich diets can encourage bacterial and fungal growth, contributing to thicker TCs, while acidic foods may alter oral pH, fostering microbial imbalances. (Hu et al. 2018).

3.6 The link between tongue coating, periodontal disease and halitosis

Significant variations in thickness and extent of TCs can be influenced by oral conditions such as periodontal status and intra-oral halitosis (IOH). Among individuals with healthy periodontium, those with IOH demonstrated a greater thickness of TCs compared to those without IOH (Oho et al. 2001; Washio et al. 2005) Conversely, individuals with periodontal disease exhibited approximately four times more TC (measured by wet weight) than those with healthy periodontal tissues. (Calil et al. 2009; Yaegaki and Sanada 1992a; 1992b) It has been suggested that the increase in TC thickness associated with periodontal disease is attributed to the migration of leukocytes from periodontal pockets into saliva, which are deposited on the tongue surface. (Yaegaki and Sanada 1992a) TC is associated with IOH, because it serves as a breeding ground for bacteria that produce VSCs. These compounds, particularly hydrogen sulfide, methyl mercaptan, and dimethyl sulfide, are the main contributors for the malodor associated with halitosis. (Liu et al. 2006; Porter and Scully 2006) When halitosis is attributed to oral sources, a heavy tongue coating is present in around half of the cases. (Quirynen et al. 2009).

Several studies examined the correlation between VSCs, TC, and periodontal diseases. (Bosy et al. 1994; Calil et al. 2009; Hinode et al. 2003; Miyazaki et al. 1995; Yaegaki and Sanada 1992b) According to Miyazaki et al. (1995) TC was

significantly correlated with VSCs levels in all age groups. The study concluded that TC is a major source of halitosis, especially in younger individuals. (Miyazaki et al. 1995) Another study by Yaegaki and Sanada (1992a) confirmed that VSC levels were higher in patients with periodontal disease compared to controls. (Yaegaki and Sanada 1992a, b) Additional support for this concept was provided by Coli and Tonzetich (1992) who reported a direct relationship between VSC levels in oral air and the severity of periodontal pocket depths, and the presence of gingival bleeding. (Coli and Tonzetich 1992) However, other investigations revealed a weaker correlation between VSC levels and periodontal conditions. (Bosy et al. 1994; Calil et al. 2009) The role of TC as a direct cause of gingivitis or periodontitis remains debatable. In this regard, TC thickness showed no significant correlation with gingivitis or bleeding upon probing. (Van Gils et al. 2020).

3.7 Systemic implications of tongue coating

TC is an important indicator used in Traditional Chinese Medicine (TCM) to diagnose disease. (Anastasi et al. 2009) Conceptually, clinicians should consider if thick tongue coating contributes to systemic diseases or do systemic diseases contribute to thick tongue coating. The latter has been well documented (Table 2). On the other hand, a thick tongue coating can possibly contribute to systemic disease. Research has suggested there is a link between bacteria present intraorally and development of chronic conditions like diabetes, gastritis, certain cancers and cardiovascular disease. This is believed to be due to the possible relocation of microbes to other parts of the body and contribute to inflammation. (Abe et al. 2008; Deng et al. 2006).

A healthy tongue should be pale pink in appearance, and it is normal to have a slightly coated tongue. However, if the coating on the tongue cannot be removed with oral hygiene, it may be a sign of an underlying health condition. Different coating colors may indicate various health issues (Table 2). (Adya et al. 2018; Gurvits and Tan 2014; Hassoon et al. 2024; Hsu et al. 2016, 2019; Seerangaiyan et al. 2018; Ye et al. 2016) In addition, TC microbiome can distinguish individuals with systemic diseases from healthy controls. (Sun et al. 2018) Recently, Liu et al. (2024) analyzed the biology of tongue coating in relation to different phases of rheumatoid arthritis (RA). In this regard, patients with RA exhibited a significantly higher presence of bacteria such as *Prevotella*, *Veillonella*, *Rothia*, and *Neisseria* than those in the healthy control group. Furthermore, during active rheumatoid arthritis, the TC harbored a greater proportion of *Veillonella*, *Rothia*, and *Neisseria* compared to the inactive phase. (Liu et al. 2024) With respect to diabetes 2, Hsu et al. (2019) reported that patients with diabetes exhibited a significantly larger area of yellow coating, thicker fur, and a bluish tongue compared to the control group. (Hsu et al. 2019) Relevant to kidney disease, Pieralisi et al. (2016) found patients exhibited a high prevalence of TC, which was often colonized by yeasts (ie *Candida albicans* and *Candida parapsilosis)*. Furthermore, their study suggests that

Table 2 Correlating tongue coating color with diseases or conditions

Tongue Coating Color	Associated Disease/Condition	Key Notes
White (Seerangaiyan et al. 2018)	- Oral candidiasis (thrush) - Diabetes mellitus - Gastric disorders - Lichen Planus - Leukoplakia	Thick white coating may indicate fungal overgrowth (Candida) or systemic diseases like diabetes
Yellow (Hsu et al. 2019; Ye et al. 2016)	- Gastric disorders (H. pylori infection) - Liver disease - Respiratory infections - DM	Yellow coating often suggests digestive problems, bile accumulation, or bacterial infections
Grayish/Black (Black Hairy Tongue) (Gurvits and Tan 2014)	- Smoking - Poor oral hygiene - Antibiotic use - Fungal overgrowth	Caused by keratin buildup, often linked to altered oral flora or medication effects
Red (Strawberry Tongue) (Adya et al. 2018)	- Vitamin B12 deficiency - Scarlet fever - Kawasaki disease	Smooth and inflamed tongue surface due to nutrient deficiency or systemic inflammation
Green (Hassoon et al. 2024)	- Respiratory infections - Fungal infections - Antibiotic resistance	May indicate a bacterial or fungal overgrowth, particularly in immunocompromised individuals
Purple or Blue (Hsu et al. 2016)	- Cardiovascular diseases - Blood circulation problems - Cyanosis	Linked to oxygen deprivation, poor circulation, or cardiovascular disorders

Candida species (fungi) should be recognized as significant components of the microbial community within TCs. (Pieralisi et al. 2016) It was also noted that individuals with aspiration pneumonia manifested a thick TC. It was suggested that a tongue coating may serve as a risk indicator for aspiration pneumonia in edentulous individuals. (Abe et al. 2008).

Conditions like diabetes, GERD, immune deficiencies and the frequent use of medications, including antibiotics and steroids, can also alter the oral microbiome, encouraging tongue discoloration, microbial imbalances and infections. (Ogami et al. 2018) With regard to diagnostic differentiation between oral and systemic conditions, it should be noted that common tongue conditions manifesting tongue coating can be improved with oral hygiene. A tongue scraper should be able to remove a tongue coating. If the coating is resistant to removal, then additional diagnostic methods (eg culture) must be used to determine the TCs etiology. In general, patients with thick persistent tongue coatings that are chronically present and do not respond to conventional hygiene methods and are associated with other symptoms should be referred to their physician for additional testing.

3.8 Management of tongue coating (Table 3)

Oral hygiene plays a major role in controlling tongue coatings by reducing deposits on the tongue. Managing TC may involve a possible combination of mechanical cleaning, chemical treatments, and addressing underlying health issues that may contribute to its buildup. (Danser et al. 2003) The American Dental Association (https://www.mouthhealthy.org/all-topics-a-z/tongue-scrapers) advocates for daily patient tongue cleaning consisting of tongue brushing or scraping before bedtime. Research has shown that regular use of tongue scrapers (once a day) or soft-bristled toothbrushes can significantly reduce the thickness of TC, bacterial load, and VSCs compounds. (Kuo et al. 2013; Outhouse et al. 2016; Tribble et al. 2019; Van der Sleen et al. 2010) For instance, Seemann's et al. (2001) found that utilizing a tongue cleaner, which combines a toothbrush, and a tongue scraper is more efficient in reducing bad breath than using either a regular toothbrush or a tongue scraper alone. (Seemann et al. 2001) In addition, Dwivedi et al. (2019) reported a significant reduction in aerobic and anaerobic bacterial load with different commercially available tongue scrapers. (Dwivedi et al. 2019).

Chemical treatments, including antimicrobial mouthrinses can complement mechanical cleaning. Solutions containing chlorhexidine, hydrogen peroxide, and povidone-iodine are effective in lowering tongue bacterial counts. (Funahara et al. 2021) Pertinently Funahara et al. (2020) conducted a randomized controlled trial to evaluate the effects of tongue cleaning with a brush combined with three disinfectants: benzethonium chloride, povidone iodine, and hydrogen peroxide compared to tap water as a control group. The results demonstrated a significant reduction in bacterial counts when tongue brushing was performed using 7% povidone iodine or 3% hydrogen peroxide solutions. In contrast, 0.2% benzethonium chloride and tap water showed no significant reduction in bacterial levels. (Funahara et al. 2020) The optimal concentration and duration for tongue cleaning were not determined.

Maintaining adequate oral hydration and stimulating saliva production can help prevent dry mouth, which worsens TC. As previously mentioned, dietary changes, such as avoiding fatty or sticky foods, can minimize coating accumulation. (Van Tornout et al. 2013) Similarly, managing systemic conditions like diabetes, gastrointestinal issues,

Table 3 Methods to enhance tongue cleansing (www.bsom.org.uk)

Action	Details/Steps	Notes/Warnings
Stop Smoking	Smoking cessation may reduce tongue coating	Provides overall health benefits
Eat Rough Foods	Include raw fruits and vegetables in your diet	-
Pineapple or Rhubarb Method	Cut a thin slice of pineapple into eight equal pieces. Place one piece at the posterior part of the tongue and allow it to dissolve for approximately one minute before chewing it slowly. Repeat the process with the remaining pieces. Perform this twice daily for one week. Rhubarb may be used as an alternative	-
Dry Peach Stone	Suck on a dry peach stone to help with hairy tongue	WARNING: Avoid swallowing or inhaling the stone
Chew Sugar-Free Gum	Chew gum to stimulate saliva flow	-
Tongue Cleaning	Use a toothbrush or tongue scraper for daily oral hygiene	Clean the tongue with a separate toothbrush, but avoid over-cleaning, which may aggravate the issue
Stay Hydrated	Drink plenty of water to maintain hydration	-
Use Certain Mouthwashes	Mouthwashes with fizzing action (e.g., hydrogen peroxide, bicarbonate of soda, or ascorbic acid) help remove debris	Avoid mouthwashes like chlorhexidine that may cause staining or irritation

and respiratory diseases may help reduce TC formation. (Li et al. 2021).

In cases where fungal infections, such as *Candida albicans*, are present, antifungal treatments may be required, such as Nystatin oral suspension, Ketoconazole and Fluconazole. (Krishnan 2012) For patients with severe TC linked to periodontal disease, professional periodontal care can help control bacterial reservoirs found in the tonsil area, saliva and on the tongue. (Acar et al. 2019) The British Society of Oral Medicine stated that removing tongue coatings can be challenging, but steps like quitting smoking, eating raw fruits and vegetables, chewing sugar-free gum, staying hydrated, and cleaning the tongue with a scraper, or toothbrush and mouthwash can help reduce the amount of TC. (www.bsom.org.uk).

In general, considering that saliva flow is reduced nocturnally and tongue coatings are usually thicker in the morning, it is a good idea to cleanse the tongue in the morning. Furthermore, since the main cause of halitosis is bacterial on the tongue, the use of a tongue scraper, which usually can eliminate halitosis may help differentiate between halitosis caused by tongue coating or a systemic issue.

3.9 Impact of tongue coating on taste sensation

The TC forms a physical barrier on the taste buds, hindering the proper interaction between taste receptors and food molecules. This can lead to a reduction in taste buds sensitivity and diminished ability to perceive tastes such as sweet, sour, salty, and bitter. (Naritasari et al. 2021) Over time, this may affect an individual's appetite and overall enjoyment of food. (Madiloggovit et al. 2016; Solemdal et al. 2012; Timmesfeld et al. 2021) Maintaining proper oral hygiene, including regular tongue cleaning, is essential to ensure optimal taste function and prevent long-term taste disturbances associated with TC. (Quirynen et al. 2004; Timmesfeld et al. 2021).

3.10 Future direction

Future investigations into the relationship between TCs, oral and systemic health should aim to uncover the microbial dynamics linking tongue biofilm and disease entities. Specifically, with respect to periodontal diseases, utilizing advanced techniques such as metagenomics and proteomics could help identify specific microorganisms and metabolic byproducts within TCs that influence periodontal inflammation. Long-term studies are also necessary to establish whether TCs play a direct role in the onset and progression of periodontal diseases. Research should examine the potential of TCs to act as reservoirs for pathogenic bacteria that may contribute to reinfection after periodontal therapy. These findings may support the integration of tongue hygiene practices into periodontal maintenance programs.

4 Conclusion

TC inspection is often overlooked as a critical component of an oral examination. The tongue provides a significant reservoir for pathogenic bacteria and can contribute to oral and systemic diseases. Effective management strategies, including mechanical cleaning, antimicrobial rinses, dietary adjustments, and addressing underlying systemic conditions are pivotal in controlling TC. Regular tongue hygiene practices, integrated into daily oral care, can mitigate health risks and improve taste sensation, and enhance overall quality of life.

Acknowledgements The author wishes to express sincere gratitude to the Deanship of Scientific Research at King Saud University.

Author contributions Conceptualization, Data collection, Investigation, Methodology, Resources, Validation, Visualization, Writing – original draft, Writing – review & editing—S.A.

Data availability Not applicable.

Declarations None.

Financial support and sponsorship None.

Informed consent Informed consent for this type of study, formal consent is not required.

Competing interests The authors report no conflicts of interest related to this article.

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