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REVIEW

Halitosis: the multidisciplinary approach

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Halitosis, bad breath or oral malodour are all synonyms for the same pathology. Halitosis has a large social and economic impact. For the majority of patients suffering from bad breath, it causes embarrassment and affects their social communication and life. Moreover, halitosis can be indicative of underlying diseases. Only a limited number of scientific publications were presented in this field until 1995. Ever since, a large amount of research is published, often with lack of evidence. In general, intraoral conditions, like insufficient dental hygiene, periodontitis or tongue coating are considered to be the most important cause (85%) for halitosis. Therefore, dentists and periodontologists are the first-line professionals to be confronted with this problem. They should be well aware of the origin, the detection and especially of the treatment of this pathology. In addition, ear–nose–throat-associated (10%) or gastrointestinal/endocrinological (5%) disorders may contribute to the problem. In the case of halitophobia, psychiatrical or psychological problems may be present. Bad breath needs a multidisciplinary team approach: dentists, periodontologists, specialists in family medicine, ear–nose–throat surgeons, internal medicine and psychiatry need to be updated in this field, which still is surrounded by a large taboo. Multidisciplinary bad breath clinics offer the best environment to examine and treat this pathology that affects around 25% of the whole population. This article describes the origin, detection and treatment of halitosis, regarded from the different etiological origins.
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EPIDEMIOLOGY

The amount of epidemiological research on bad breath is limited, since this topic is still a large but underestimated taboo. A public investigation in 2005 in The Netherlands showed that halitosis was one of the 100 biggest human overall exasperations (TNS-NIPO).

There are several reasons for this lack of scientific data. First, there is the difference in cultural and racial appreciation of odours, as for patients as well as for investigators.[1] Second, there is absence of uniformity in evaluation methods, as for organoleptical as for mechanical measurements.

A cross-sectional Brazilian study among university students and their families, showed a malodour incidence of 15%. Men suffered more from the problem than women, especially when they were over 20 years.[2] Japanese researchers investigated 33 000 adults. Fifteen per cent of them declared to suffer from bad breath, with a peak of more than 20% in the city of Tokyo.[3] Moreover, 70% of the businessmen in Tokyo detected regularly a personal halitosis. In China, more than 25% of a population of 2 000 individuals seems to be suffering from halitosis.[4] Al-Ansari *et al.*[5] showed also in 2006 the same incidence in a Kuwaiti population of 1 500 people. In general, nearly of 25% of the population seems to suffer from bad breath on a regular basis.

Man and women seem to suffer in the same proportions, whereas women seem to seek faster for professional help than men.[6] Miyazaki found that there is a clear correlation between age and oral malodour: the older one gets, the more intense the odour will become.[7] In the United States, Loesche *et al.*[8] found that 43% of people over 60 had breath problems. Whereas in the same Group of Turkish individuals, the incidence seemed to be around 28%.[9] Bornstein *et al.*[10] found nearly the same incidence in Swiss city of Bern. These results suggest that this oral malodour is caused by tongue coating in the younger generation and by periodontitis with tongue coating in the older cohorts.

This large variety of data suggest that there are large shortcomings in the methodology of the overall research projects.[11] A standardized evaluation protocol for halitosis studies is needed to compare epidemiological data. Therefore, a mechanical detection method should be used as golden standard for bad breath research.

ORIGIN

Microbial degradation in the oral cavity is the main cause of oral malodour. Due to this process, volatile sulphur compounds (VSCs) are formed. The most important VSCs involved in halitosis are hydrogen sulphide (H_2S), methyl mercaptan (CH_3SH) and dimethyl sulphide $(CH_3)_2S$. These VSCs are mainly produced by Gram-negative anaerobic oral bacteria.[12] Other molecules involved in this bacterial degradation process are: diamines (indole and skatole) or polyamines (cadverin and putrescin). They seem play a less important role in the expression of bad breath.

Most of these components are produced in the proteolytic degradation process of peptides. The most predominant substrates in this VSC production are cysteine, cystine and methionine.[13] The main substrate for skatole and indole production is tryptophan, whereas lysine and ornithine are the basis for the putrescin/cadaverin production. The involved bacteria in these metabolic processes are shown in Table 1.

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Table 1 Bacteria responsible for VSC production

Volatile sulphur compounds	Bacteria
H_2S from cysteine	*Peptosteptococcus anaerobius*
	Micros prevotii
	Eubacterium limosum
	Bacteroides spp.
	Centipedia periodontii
H_2S from serum	*Prevotella intermedia*
	Prevotella loescheii
	Porphyromonas gingivalis (BANA positive)
	Treponema denticola (BANA positive)
	Selenomonas artermidis
CH_3SH from methionine	*Fusobacterium nucleatum*
	Fusobacterium periodonticum
	Eubacterium spp.
	Bacteroides spp.
CH_3SH from serum	*Treponema denticola* (BANA positive)
	Porphyromonas gingivalis (BANA positive)
	Porphyromonas endodontalis
Other	*Prevotella melaninogenica*
	Tanerella forsythensis
	Eikenella corrodens
	Solobacterium moorei
	Treponema forsythensis
	Centipeda periodontii
	Atopobium parvulum

Adapted from Persson *et al.*[120]

Most of the responsible microorganisms in halitosis are involved in periodontitis. So, there is a positive correlation between bad breath and periodontitis: the depth of the periodontal pockets is positively correlated to the height of the VSC concentrations in the mouth.[14] When tongue coating is taken into account, the correlation is even more significant.[15–16] Individuals with a healthy periodontium can show halitosis caused by the impaction of food, bacteria, leucocytes and desquamating epithelial cells on the dorsum of their tongue. This surface is large and has a high retention capacity due to the rough and papillary structure. The bacterial composition on the dorsum of the tongue seems to be identical to the subgingival plaque.[17] Table 2 shows the main volatile molecules contributing to oral malodour.

Table 2 Volatile molecules contributing to oral malodour

Categories	Compounds
Volatile sulphur compounds	Methyl mercaptan: CH_3SH
	Hydrogen sulphide: H_2S
	Dimethyl sulphide: $(CH_3)_2S$
Diamines	Putrescine: $NH_2(CH_2)_4NH_2$
	Cadaverine: $NH_2(CH_2)_5NH_2$
	Butyric acid: $CH_3CH_2CH_2COOH$
	Propionic acid: CH_3CH_2COOH
	Valeric acid: $C_5H_{10}O_2$
Phenyl compounds	Indole: C_8H_7N
	Skatole: C_9H_9N
	Pyridine: C_5H_5N
Alcohols	1-propoxy-2-propanol
Alkalines	2-methy-propane
Nitrogen-containing compounds	Urea: $(NH_2)_2CO$
	Ammonia: NH_3
Ketones	

Adapted from Goldberg *et al.*,[13] Greenman *et al.*[17] and Claus *et al.*[121]

Oral pathology, microbiology and xerostomia

In nearly 85% of all halitosis cases, the origin is found in the oral cavity. A clinical evaluation of malodour on 2 000 patients in Belgium, showed that 76% of these patients had oral causes: tongue coating (43%), gingivitis/periodontitis (11%) or a combination of the two (18%).[18]

Tongue coating. This phenomenon is the most common cause of bad breath.[19] The dorsum of the tongue, which is irregular and has a surface of 25 cm^2 is an ideal niche for oral bacteria.[20] Since desquamating epithelial cells and food remnants are available, putrefaction occurs. Hence, the tongue surface seems to be an important reservoir in the recolonisation of tooth surfaces.[21] Tongue coating is not easy to remove. Daily scraping or brushing of the tongue can help to reduce the substrata for putrefaction, rather than to reduce the bacterial load. Moreover, tongue cleaning improves taste sensation.[22]

Morning breath. Due to the reduced saliva production during night, anaerobic putrefaction will increase, causing the typical morning breath. This is a non-pathological form of halitosis. The problem will disappear as soon as oral hygiene measures are taken. Snel *et al.*[23] concluded that gender seems to play an unknown role in this phenomenon: women manifest higher VSC levels than men in the morning. This phenomenon needs to be further investigated to understand its impact.

Odontogenic halitosis. Poor oral hygiene, dental plaque, dental caries, accumulation and putrefaction of food remnants and unclean acrylic dentures (worn at night or not regularly cleaned or with rough surfaces) contribute to bad breath. The latter was recently concluded in a systematic review, stating that, although isolated reports, chemicals and brushing appear to be more effective than placebo in the reduction of plaque coverage and microbial counts of anaerobes and aerobes on complete denture bases.[24]

Gingivitis and periodontitis are the main causes of the problem.[25] A positive correlation between the depth of the pockets and the concentration of the sulphur components has been shown.[15] Necrotizing gingivitis or periodontitis cause extreme soiled odours. This disease is caused by opportunistic bacterial infections occurring in individuals with stress, malnutrition, insufficient oral hygiene, smoking or systemic diseases.[26]

Xerostomia. Patients with a dry mouth (0.15 $mL \cdot min^{-1}$ instead of 0.25–0.50 $mL \cdot min^{-1}$) often show an increased volume of plaque on teeth and tongue.[27] The lack of salivary flow, leads to the disappearance of the antimicrobial activity of the saliva and the transition from Gram-positive bacteria to Gram-negative species.[28] Hyposialy can be caused by diabetes, Sjögren syndrome, stress, depression, medication, mouth breathing and alcohol abuse. Almost 25% of the elderly suffer from a dry mouth.[29] Research groups of Kleinberg and Koshimune described properly the correlation between the dry mouth and the increase of halitosis.[30–31]

Moreover, other salivary factors can influence the development of malodour: an increase of the salivary pH by the intake of amino acids, and a change in the oxygen depletion (a reduction stimulates the metabolism of Gram-negative bacteria, responsible for higher VSC production).[32–33]

A recent study in elderly found the accumulation of bacterial plaque on the tongue, oral dryness, burning mouth, overnight denture

wear, and lower educational levels to be significantly related to oral malodour.[34]

Although xerostomia is associated with aging, studies have demonstrated that salivary gland function is well preserved in the healthy geriatric population. Therefore, dry mouth is probably a condition of systemic or extrinsic origin. Saliva seems to undergo chemical changes with aging. As the amount of ptyalin decreases and mucin increases, saliva becomes thick and viscous and presents problems for the elderly. One of the most prevalent causes of xerostomia is medication (anticholinergics, antihistamines and diuretics dry the mucosa). Chronic mouth breathing, radiation therapy, dehydration and autoimmune diseases (as Sjögren's) can also diminish salivation, as can systemic illness such as diabetes mellitus, nephritis and thyroid dysfunction.

Xerostomia can lead to dysgeusia, glossodynia, sialadenitis, cracking and fissuring of the oral mucosa, and halitosis. Dry mouth symptom can be treated with hydration and sialagogues or with artificial saliva substitutes. In patients with Sjögren's syndrome and in those who have undergone radiation therapy, pilocarpine has been used with good results.[35]

Other oral causes. Stomatitis, intra-oral neoplasia, exposed tooth pulps (with necrotic content), extraction wounds (with blood cloth or purulent discharges), or crowding of teeth (favouring food entrapment) can also be involved.[36] Moreover, peri-implantitis, peri-coronitis, recurrent oral ulcerations and herpetic gingivitis, are described as origin for bad breath.[37]

ENT and pulmonary pathology

Maximally 10% of the oral malodour cases originate from the ears, nose and throat (ENT) region, from which 3% finds its origin at the tonsils.[38] Very seldom the larynx is involved. Therefore, when a clinical investigation is performed, attention should first be paid to the tonsils: size, structure (invaginations, coating and hyperaemia) and presence of tonsilloliths.[39]

Oral causes. Acute tonsillitis is the most important ENT origin. Mostly, infections with *streptococci* play a role, but also viral infections (e.g. mononucleosis infectiosa) are possible. When acute tonsillitis takes place more than three times a year, a tonsillectomy can be considered.[40] A Plaut-Vincent angina (caused by *Fusobacterium Plaut-Vincenti* and *Borrelia Vincenti*) is another ENT cause for halitosis.[41]

The presence of tonsilloliths represents a 10-fold increased risk of abnormal VSC levels.[42] Anaerobic bacteria detected in tonsilloliths belonged to the species of *Eubacterium*, *Fusobacterium*, *Porphyromonas*, *Prevotella*, *Selenomonas* and *Tanerella*, all of which appear to be associated with the production of VSCs.[43] Tonsillliliths are asymptomatic phenomena and are therefore never a reason for tonsillectomy.

A tonsillectomy is only performed when oral hygiene measures do not result in improvement of the breath.

Nasal causes. Postnasal drip (caused by mucus of the paranasal sinuses) contacting the dorsum of the tongue is largely involved.[44] Foreign bodies in the nasal cavity can produce a foul odour as well. Also a cleft palate can be the origin of bad breath.[45] Atrophic rhinitis with bacterial surinfection causes malodour too. This can be caused by tumor rescetions, radiotherapy or overuse of decongestives or cocaine.

Sinusitis. Bacterial sinusitis develops mostly out of acute viral sinusitis. *Streptococcus pneumonia* and *Haemophilus influenza* are the main responsible bacteria. On radiological or computed tomography (CT) images, fading is perceived. When purulent mucous is produced, a typical odour appears. In 10% of the sinusitis cases, a tooth or several teeth are involved. In these cases, the spotted bacteria are: *Peptostretococcus* spp., *Fusobacterium* spp., *Prevotella* spp. and *Porphyromonas* spp. Since those bacteria are able to produce VSCs, a clear association to halitosis is available. The treatment of dentogenic problems (eventual with the additional use of antibiotics) decreases the anaerobic pathogens, even as the odour problem. In the case of chronic sinusitis, 50%–70% of the patients complain about oral malodour.[46]

Pulmonary pathology. bronchiectasis, lung abscesses and other endobrochial chronic disorders, i.e. necrotizing pulmonic neoplasias may cause an unpleasant odour.[47]

Gastro-intestinal pathology

The gastro-intestinal tract can only indirectly (haematogenic) influence bad breath. A majority of patients and physicians still abusively believes that halitosis originates from the stomach. The latter is only correct in $<0.5\%$ of the cases.

Oesophagus. Only in specific cases, this is the origin of malodour. When a Zenker's diverticulum is present, a chronic unpleasant odour appears.[48] The incidence of this phenomenon is less than 0.1% and it is only diagnosed in patients over 65 years of age. Also bleeding of the oesophagus can cause a musty odour. When severe regurgitation is determined, halitosis will be present.[49] Symptomatically, coughing, postnasal drip, pyrosis, irritations and ulcerations of the oesophagus and halitosis will be detected. pH monitoring is used for diagnosis. When the diagnosis is missed, carcinomatic deterioration can occur.

Stomach. Infections with *Helicobacter pylori* can cause peptic ulcers. There is no 100% clear correlation found between these ulcers and halitosis.[50–51] *In vitro* studies show significant VSC production by *H. pylori*.[52] More recent research by Lee *et al.*[53] confirmed this statement. Moreover, it is suggested that *H. pylori* was detected in subjects with periodontitis, suggesting that progression of periodontal pocket and inflammation may favour colonization by this species and that *H. pylori* infection may be indirectly associated with oral pathological halitosis following periodontitis.[54] Kinberg *et al.*[55] showed that halitosis has often been reported among the symptoms related to *H. pylori* infection and gastroesophageal reflux disease. When gastrointestinal pathology was treated, most of the halitosis complaints disappeared. The latter suggests that halitosis can have a gastro-intestinal origin. In a recent comparative study among children in Turkey, it was concluded that there was a difference between the rate of *H. pylori* infections among those with and without halitosis. Eradication treatment was found beneficial in the treatment of children with halitosis and positive *H. pylori* stool antigen test. The results, however, were not statistical significant.[56]

In general, it can be concluded that more research has to be done to clarify a clear correlation between stomach problems by *H. pylori* infections and halitosis.

Intestines. In cases of intestinal obstruction, a faecal mouth odour may be detectable, as found in two siblings with extrinsic duodenal obstruction caused by congenital peritoneal bands.[57] Attention was drawn to the unusual physical sign of halitosis as a presenting feature. It was suggested that this physical sign may be an indication for barium studies.

Metabolic disorders

Preti *et al.*[58] discussed already in 1992 a number of non-oral causes for oral malodour. Several well-documented aetiologies for non-oral malodour include renal failure, cirrhosis of the liver and diabetes mellitus. In addition, there appeared to be several other metabolic conditions involving enzymatic and transport anomalies (such as trimethylaminuria) which lead to the systemic production of volatile malodours that manifest themselves as halitosis and/or altered chemoreception.

Renal disease in the form of chronic renal failure is associated with high blood urea nitrogen levels and low salivary flow rates. Peritoneal dialysis decreased the problem.[59] The dispersed odour is a typical uremic odour in combination with a dry mouth. Also pancreatic insufficiencies can cause oral bad odours as found by Feller and Blignaut in 2005.[60]

Diabetic ketoacidosis leads to a typical breath odour.[61] Diabetes type 2 demonstrates a typical sweet and fruity odour.[62] Due to gas chromatography–mass spectrometry, it seems possible to detect different extra-oral causes of halitosis such as diabetes.[63]

Several metabolic disorders in the bowels, like trimethylaminuria cause a specific fishy odour. According to Whittle *et al.*,[64] this genetic disease is the largest cause of undiagnosed body odour. Trimethylaminuria is a disorder in which the volatile, fish-smelling compound, trimethylamine accumulates and is excreted in the urine, but it is also found in the sweat and breath. Because many patients have associated body odours or halitosis, trimethylaminuria sufferers can meet serious difficulties in their social context, leading to isolation and even depression. Trimethylamine is formed by bacteria in the mammalian gut from reduction of compounds such as trimethylamine-*N*-oxide and choline. Primary trimethylaminuria sufferers have an inherited enzyme deficiency where trimethylamine is not efficiently converted to the non-odorous trimethylamine-*N*-oxide in the liver. Diagnosis of trimethylaminuria requires the measurement of trimethylamine and trimethylamine-*N*-oxide in urine, which should be collected after a high substrate meal in milder or intermittent cases, a marine-fish meal. The symptoms of trimethylaminuria can be improved by changes in the diet to avoid precursors, in particular trimethylamine-*N*-oxide which is found in high concentrations in marine fish. Treatment with antibiotics to control bacteria in the gut, or activated charcoal to sequester trimethylamine, may also be beneficial.[65]

Recently, an article by Scully and Greenman[66] reviewed the aetiopathogenesis of halitosis. They stated that only in a few patients, metabolic anomalies are responsible. If this condition is present, the extra-oral origin should be determined, because the latter requires medical investigation and support in therapy.

Hepathology and endocrinology

The liver can be involved in oral malodour. Due to a reduced liver function, waste products are eliminated through the lungs, causing the 'fetor hepticus': a sweet, excremental odour (the breath of death). Fetor hepaticus is an expression of hepatic encephalopathy.[67] Liver failure inhibits the detoxification in the whole body, causing unpleasant odours.[68] Also some hereditary disorders can influence the breath: tyrosinemy is the most important example (cabbage odour).

Endocrinology can also contribute to halitosis. Not only the hormonal cycle seems to influence the mouth odour, but also a lot of other intestinal diseases.[69–70]

Recently, van Steenberghe mentioned a whole list of metabolic and endocrinological aspects in correlation to oral malodour.[62] This list is resumed in Table 3.

Table 3 Odours in the case of metabolic or endocrinological problems

Odours	Metabolic or endocrinological problems
Fruity odour	Type-1-diabetes in children
	Type-2-diabetes in adults
	Alcoholic ketoacidosis
Faecal odour	Intestinal obstruction
Ammonia of fishy odour	Kidney-insufficiency
	Trimethylaminuria
Mouse odour	Phenylketonuria
Cooked cabbage odour	Methionine adenosyl transferase deficiency
Sweating feet odour	Isovaleriaan acidity
	Deficiency on chromosome 15
Burned sugar odour	Maple syrup urine disease
Sweet musty odour	Homocystinuria
Rotten eggs odour	Disease of Lignac

Adapted from van Steenberge.[62]

Medication

Next to medication resulting in a dry mouth (see above); recently the use of bisphosphonates can contribute to oral malodour. Bisphosphonate-induced osteonecrosis is since 2003 a common problem.[71] The product is used systemically in cases of malignant bone tumours and their metastases. Often this results in jawbone necrosis, a clear origin for a filthy odour. The necrotic sequesters should be removed and it is tried to cover up the necrotic area with a steeled flap.[72]

DETECTION

The gold standard is the organoleptic scoring, i.e., smelling the odour of the patient. A more objective method is the analysis of breath samples by gas chromatography or by means of portable VSC analysers.

Organoleptic scoring

In expired air, more than 150 different components have been detected. The perception of these molecules is dependent of the olfactory response, the threshold concentration, the strength of the odour and the volatility of the molecules. When organoleptical scoring is performed, a well-trained clinician determines if the odour samples smells bad or not, giving a score to the intensity. Theses scores go from 0 up to 5 (Table 4).

From every patient, different samples are analysed:

- mouth odour (smelled at 10 cm form the oral cavity: while the patient normally breaths and while the patient counts loudly to 10);
- saliva odour (measured by the wrist-lick test: the patient licks at the wrist, and after 10 s of drying, a score is given to this sample);
- tongue coating (a score is given to debris, scraped from the dorsum of the tongue with a periodontal probe);

Table 4 Organoleptical scoring scale

Rosenberg & McCulloch scale	Description
0	No detectable odour
1	Hardly detectable odour
2	Light odour
3	Moderate odour
4	Strong odour
5	Extremely strong odour

Adapted from Rosenberg and McCulloch.[75]

- interdental 'floss' (after flossing with dental tape, the odour of the floss is scored);
- nasal odour (while the patient is breathing through the nose (mouth closed), a score is given to the exhaled air);
- prosthesis odour (if the patient wears a partial or full removable denture, scoring of the odour of this prosthetic is noted).

To gather optimal test results several precautions should be taken before the examinations: the patient should refrain from spicy foods, garlic or onions the day before the examination. At least 12 h before the consultation, teeth should not be cleaned or rinsed, perfumes should be avoided and at least 6 h before the examination, the intake of food or liquids should be avoided. Smoking should be stopped at least 24 h before any examination.[73]

The advantages of organoleptical scoring are: inexpensive, no equipment needed and a wide range of odours is detectable. As disadvantages, the extreme subjectivity of the test, the lack of quantification, the saturation of the nose and the reproducibility can be mentioned.[74] Still, organoleptic scoring is considered as the gold standard in the detection of oral bad breath.

Portable gas analysis

The Halimeter (Interscan corporation, Chatsworth, CA, USA) and OralChroma (Abimedical corporation, Miyamae-ku Kawasaki-shi, Kanagawa, Japan) are electronic devices available to detect some of the volatile sulphur components in expired air. The OralChroma is a portable gas chromatograph offering lower cost, higher performance and more user-friendly operations than conventional gas chromatographs by limiting the target gases to three types: H_2S, CH_3SH and $(CH_3)_2S$. Also, an interpretation of the results can be shown to the patients.

The Halimeter can only give an idea of the total amount of VSCs, present in a sample. In the Halimeter, the total amount ppb (parts per billion) of VSCs in the sample is marked. In normal situations this value is less than 100 ppb. When 300–400 ppb are detected in the mouth air, a persistent oral odour can be concluded.[15,75]

These portable machines have a lot of advantages: easy to handle, fast results, portable and reproducible. Furthermore, they are rather inexpensive and can be controlled by untrained staff. As disadvantage, the limited diversity in the explored gasses should be stated. Recently, it was shown that the OralChroma may produce a more comprehensive assessment of VSC production by oral microflora than the Halimeter.[76] It would desirable to select one machine as gold standard to make different studies comparable in the future.

Gas chromatography

In halitosis research, the gas chromatography (GC) analysis can be performed on breath, saliva and tongue debris. Almost all different air components can be detected. In expired air, almost 500 different substances can be demonstrated.[77] GC in malodour research is still in an experimental stage, although used since the late 1960s.[78] VSCs can be well detected, but the challenge will be to analyse the other contributing components of oral malodour. Also the associations of different odours with specific systemic disease can and should be investigated.

GC has several advantages: an analysis of almost all components with high sensitivity and specificity. The method is non-invasive, but expensive and a well-trained staff is needed. The progression of the method takes much more time and the machine cannot be used in daily practice.[79]

Recently, trailblazing research was performed by van den Velde *et al.*[63,68] with gas chromatography–mass spectrometry as a tool for differential diagnosis of halitosis, with the possibility to detect extra-oral causes, which often remain undetected unless characterized by a specific smell.

THERAPY

Oral causes

Since the oral causes are related to microorganisms, the therapy can consist of: (i) mechanical reduction of the intra-oral nutrients and micro-organisms; (ii) chemical reduction of microorganisms; (iii) inverting volatile fragrant gasses into non-volatile components or (iv) masking of the malodour.[80]

Mechanical reduction. Tongue coating is the most prominent factor and therefore, extensive tongue cleaning is of utmost importance. The scraping of the dorsum of the tongue reduces the available nutrients even as the available microorganisms, leading to an improvement of the odour.[81] Home tongue cleaning can be performed with a regular toothbrush, but a specific tongue scraper is advised. A brush is less aggressive on the soft tissues.[82] Since the largest amount of coating is found on the dorsal part of the tongue surface, a cleaning as posterior as possible is advised. To prevent from vomiting, it is counselled to pull out the tongue when scraping.

A systemic review by van der Sleen *et al.*[83] demonstrated that tongue brushing or tongue scraping have the potential to successfully reduce breath odour and tongue coating. Due to tongue cleaning, the taste seems to improve again.[84] Interdental cleaning and toothbrushing are also necessary to control plaque and oral microorganisms.

A Cochrane review from 2006, compared randomized controlled trials for different methods of tongue cleaning to reduce mouth odour in adults with halitosis.[85] Only two trials were included, involving 40 participants. Due to the clinical heterogeneity between these two studies, only a descriptive summary could be made. It is concluded that there is a weak and unreliable evidence to show that there is a small but statistically significant difference in reduction of VSC levels when scrapers or cleaners rather than toothbrushes are used to reduce halitosis in adults. More coherent studies are required to come to clear conclusions.

Since periodontitis is one of the main causes of oral malodour, a professional periodontal therapy should be performed. A one-stage full-mouth disinfection, as described by Bollen *et al.*,[86] combining scaling and rootplaning in combination with chlorhexidine, has a significant microbiological improvement up to 2 months and reduces the organoleptical scores, in particular for saliva samples, who seems to be representative for organoleptical scoring.[87]

When patients' response to treatments at a multidisciplinary breath odour clinic was considered, it was concluded that education of the public and dental professionals in a more consequent general oral hygiene might elevate the level of compliance and could cause thereby an amelioration of the problem.[88]

Chemical reduction. Rinsing is a common practice in the approach of oral malodour. The most used rinsing components are:

- chlorhexidine (CHX): CHX is the most efficient molecule against plaque. Rosenberg showed that rinsing with 0.2% CHX causes a reduction of 43% in VSCs and of 50% in the organoleptical scores on a day-long basis.[89]
- essential oils: these products give only a short-term and restricted effect (25% reduction) for 3 h. Also, the reduction in odour-producing bacteria is limited.[90]

- chlordioxide: chlordioxide is a strong oxidizing product that can reduce oral malodour by the oxidation of H_2S, CH_3SH, cysteine and methionine. A reduction of 29% in odour after 4 h was reported.[91]
- triclosan: triclosan is effective against the majority of oral bacteria. An 84% reduction of VSCs after 3 h is proved.[92]
- aminefluoride/tinfluoride: the combination of AmF/SnF_2 can cause an 83% reduction in the morning halitosis.[84]
- H_2O_2: a concentration of 3% of this product can result in a 90% VSC reduction after 8 h.[93]

Toothpastes, containing stannous fluoride, zinc or triclosan, seem to have proved their beneficial effect in reducing the oral malodour for a limited period of time.[94–96]

In a recent Cochrane review by Fedorowicz, only five randomized controlled trials could be found, involving 293 participants.[97] In view of the clinical heterogeneity between the trials, pooling of the results and a meta-analysis of the extracted data was not feasible. Compared to placebo, 0.05% chlorhexidine+0.05% cetylpyridinium chloride+0.14% zinc lactate mouthrinse significantly reduced the organoleptic scores, but showed significantly more tongue and tooth staining. It is concluded that this mouthrinse plays an important role in reducing the levels of halitosis producing bacteria on the tongue and can be effective in neutralization of odoriferous sulphur compounds. But well-designed, randomized controlled trials with larger sample size, a longer intervention and follow-up period are still needed to confirm these results.

Transformation of volatile sulphur components. Metal ions with affinity for sulphur, pick up sulphur-containing gasses. Zinc, mercury and copper are the most important metals.[98] A commercial rinse (containing 0.005% CHX, 0.05% cetylpyridinium chloride (CPC) and 0.14% zinc lactate) seems to be much more efficient than CHX alone, due to the effect of zinc. Zinc plus CHX seem to have a synergistic effect as Young *et al.*[99] proved.

Masking effect. Rinsing products, sprays, mint tablets or chewing gum only have a short-term masking effect.[100] Mostly, they increase the saliva production, thereby retaining more soluble sulphur components for a short period of time.[30]

ENT and pulmonology

When problems in this area are considered, patients should be referred to an ENT specialist or a pulmonologist. Acute pharyngitis can be treated symptomatically, when a viral infection is at stake. A salicylic intake seems efficient when started from the prodromal stage onwards. Chlorhexidine sprays can prevent bacterial overgrowth and reduce the breath malodour. If pharyngitis is of bacterial origin, group A *streptococci* are mostly responsible. The infection can be confirmed by bacterial culturing or by antigen tests. Treatment with penicillin is imperative to prevent rheumatic fever. The breath malodour will soon disappear.[101] Foreign objects in the nose should be removed.

Acute infective sinusitis can be treated by an appropriate antimicrobial. Broad-spectrum penicillin or cephalosporin is the choice. Sometimes, a surgical widening of the ostia is needed, especially if recurrences are observed. If the problem is of dental origin, this infection should be treated first. Periapical tooth infections, particularly of second molars are mostly responsible. Endodontic treatment or extraction of the tooth is the options.

The treatment of chronic sinusitis is depending on the underlying cause. The problem will be treated by medications containing vasoconstrictors associated or not with H_1 antihistaminic, rinsing of the sinuses or even surgical removal of the inflamed mucosa and polyps.[102]

In the case of chronic tonsillitis, the elimination of the deep crypts, which harbour exfoliated cells, debris and bacteria, is important. Prescribing antibiotics like metronidazole has only a short-term effect. Cryptolysis by means of CO_2 laser is another option.[103] Ozena seems to respond well to a prolonged treatment of fluoroquiolone, which are highly effective against Gram-negative bacteria including *Heamophilus influenza*. Prolonged treatment can produce however some side effects as photosensibilisation or tendinitis.[104]

In the case of tonsilloliths, a proper hygiene can be instructed by squeezing out the debris out of the cryptic tonsils. This handling requires exercising.

Gastro-intestinology

In the case of regurgitation esophagitis, the treatment mostly consist of weight reduction, prohibition of coffee and tobacco, avoidance of extensive meals in the evening, placing the head of the bed in a slightly higher position. H_2 anatgonists can be prescribed.[105] When *H. pylori* infections are noticed, the therapy consists of the intake of omeprazol, amoxicillin en clarithromycin.[106]

A Zenker diverticle must be surgically removed. For a stomach hernia, generally a surgical intervention will be necessary.

Hepathology and endocrinology

In severe hepatologic problems, a liver transplantation can be necessary. In less life-threatening situations, a liver dialysis can be sufficient to treat the problems. In more simple pathology, cortisone therapy and a stringent diet can be enough.[107]

In the endocrinological range of problems, the underlying diseases should be treated. The detailed approach of these therapies falls outside the scope of this article.

Probiotics

Recently several studies were performed to replace bacteria responsible for halitosis with probiotics as *Streptococcus salivarius* (K_{12}), *Lactobacillus salivarius* or *Weissella cibaria*. The objective is to prevent re-establishment of non-desirable bacteria and thereby limit the re-occurrence of oral malodour over a prolonged period. Several studies conclude that probiotic bacterial strains, originally sourced from the indigenous oral microbiotas of healthy humans, may have potential application as adjuncts for the prevention and treatment of halitosis.[108] The oral administration of the probiotic *lactobacilli* not only seemed to improve the physiologic halitosis, but also showed beneficial effects on bleeding on probing from the periodontal pockets.[109]

Moreover, *Weisella cibaria* isolates possess the ability to inhibit VSC production under both *in vitro* and *in vivo* conditions, demonstrating that they bear the potential for development into novel probiotics for use in the oral cavity.[110] Gut-caused halitosis, although rarely occurring, can be successfully treated with a suspension of living non-pathogenic *Escherichia coli* bacteria.[111] Scully and Greenman[66] showed that emergent halitosis treatments include probiotics and vaccines targeted against causal microorganisms or their products.

PSYCHOLOGICAL ASPECTS

In general, humans cannot detect their own bad breath. Therefore, it is unusual that patients can detect their halitosis, although there is nothing wrong. This kind of patients often frequents a halitosis clinic.

Halitophobia

This is the fear of having bad breath that other people find offensive. Moreover, 0.5%–1% of the adult population is affected with this problem in their social live. These patients consider having bad breath, do not have it, but get not convinced during diagnosis and therapy. Non-real halitosis or halitophobia is understood by the compulsive idea to suffer from bad breath and to irritate others by this.

Nagel mentions that consultation hours for halitosis should be prepared for patients with non-real halitosis and build up corresponding interdisciplinary contacts.[112] The 'treatment' of these patients is impossible, since they are not into the arguments stated by a physician. Mostly, these patients hop from clinic/specialist to clinic/specialist to find an argument for their self-esteemed problem. Imagined halitosis is poorly documented in the psychiatric literature.[113] Many of the cases with imagined halitosis described in the literature resemble the psychiatric syndrome of social phobia.[114]

Olfactory reference syndrome

Olfactory reference syndrome (ORS) is defined as the psychiatric condition characterized by persistent preoccupation about body odour accompanied by shame, embarrassment, significant distress, avoidance behaviour and social isolation.[115] ORS has, however, not been included in the Diagnostic and Statistical Manual of Mental Disorders and, given that it is primary symptoms may be found in various other disorders, differential diagnosis can be problematic. ORS seems to represent a unique cluster of symptoms that can be delineated as a separate diagnostic entity, and ORS falls on a spectrum of social anxiety disorders that includes social anxiety disorder, taijin kyofusho and body dysmorphic disorder.[116]

Pseudo-halitosis

These are patients who consider to have bad breath, but who does not have it, and finally get convinced during diagnosis and therapy. Seemann describes data collected from a multidisciplinary breath consultation in Germany.[73] According to this research, 28% of these patients complaining of bad breath did not show signs of bad breath—meaning that their concern of halitosis was exaggerated. Within this group, 76% received prior treatments for bad breath, 36% received gastroscopies and 14% underwent an ENT operation—all without having detectable signs of bad breath. Only 9% of these patients went through an organoleptic evaluation before they underwent these medical procedures. Patients with pseudo-halitosis show more often symptoms of depression.[117]

Therapy

Selective Serotonin Reuptake Inhibitor, which increases the concentration of serotonin in the brain, can help to treat this phenomenon.[118] When tricyclic antidepressant medication is used, xerostomia can appear, leading to an increase of halitosis awareness.[119] Patients with symptoms of halitophobia or ORS, should not be treated by dental practitioners or by ENT specialists, but should be referred to psychologists or even to psychiatrists.

CONCLUDING REMARKS

Halitosis is a common condition, affecting around 25% of the general population. The origin of the problem largely arises from intra-oral causes, whereas only a limited number of cases are the result of extra oral or systemic problems. Nevertheless, proper investigation and management of these extra oral causes is important for the total understanding of this phenomenon. Halitosis from an extra-oral origin can be the sign of an underlying systemic disease. Therefore, it is substantiated to organize halitosis consultations in a multidisciplinary setting, assembling periodontologists, ENT specialists, specialists in internal medicine and psychologists or even psychiatrists.

Although oral malodour is mostly associated with poor oral hygiene and the presence of gingivitis or even periodontitis, evidence suggests that anaerobic microorganisms present in the tongue coating, are the overwhelming cause of this condition. A limited number of successful treatment regimens have been described, but more research on the long-term outcomes of these therapies will be required. Also new and more long lasting in-office treatments should be developed and tested.

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