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The effect of a chewing-intensive, high-fiber diet on oral halitosis

A clinical controlled study

KEYWORDS
diet,
fiber,
bad breath,
halitosis,
tongue coating

SUMMARY

Tongue coating is the most common cause of oral halitosis and eating results in its reduction. Only limited data are available on the effect of different food items on tongue coating and halitosis. Therefore, the aim of this study was to investigate the effect of a single consumption of food with high fiber content versus low fiber content on halitosis parameters.

Based on a randomized clinical cross-over study, 20 subjects were examined over a period of 2.5 hours after consumption of a high-fiber and a low-fiber meal. The determination of volatile sulfur compounds (VSC) was performed using a Halimeter, and the organoleptic assessment of halitosis was done on the basis of a distance index. The tongue coating was determined using a modified Winkel index, and the mouth sensation was evaluated subjectively by the subjects.

In both the test and the control phase, a statistically significant reduction of all selected parameters was detected ($p<0.05$). Only for the organoleptic assessment of halitosis was a statistically significantly higher reduction found after consumption of a high-fiber meal compared to the control meal ($p<0.05$).

In conclusion, the consumption of the meals in this study resulted in an at least 2.5-hour reduction of oral halitosis. The chewing-intensive (high-fiber) meal even resulted in a slightly higher reduction of oral halitosis in terms of organoleptic assessment ($p<0.05$).

Introduction

The term halitosis refers to bad breath, "Foetor ex ore" or "oral malodour" (Seemann et al. 2014). According to epidemiological studies, about a quarter of the population suffers from bad breath (Liu et al. 2006, Bornstein et al. 2009). Halitosis can develop intra- as well as extraorally. Different examinations have shown that a bacterial decomposition of organic material inside the oral cavity (mouth) is the cause of halitosis in 85% to 90% of cases (Tonzetich & Richter 1964, Tonzetich 1978, Delanghe et al. 1999, Rosenberg & Leib 1997, Seemann et al. 2014). This form of halitosis is called oral halitosis (Yaegaki & Ciol 2000, Seemann et al. 2014).

Volatile sulfur compounds (VSC), which are produced by Gram-negative anaerobic bacteria, are responsible for the development of the unpleasant odor (Tonzetich & Richter 1964, Tonzetich 1971). These VSCs are mainly the chemical compounds hydrogen sulfide H_2S, methyl mercaptan $(CH_3)SH$, and dimethyl sulfide $(CH_3)_2S$ (Tonzetich & Richter 1964, Tonzetich 1971). According to a number of estimates, about two-thirds of all oral microbes are located on the dorsum (back) of the tongue. The tongue coating itself mainly consists of blood and saliva particles, food residue, exfoliated epithelial cells, and bacteria (De Boever & Loesche 1995). Of the Gram-negative anaerobic bacteria mentioned above, Tannerella forsythia, Treponema denticola, and Porphyromonas gingivalis deserve particular mention (Bosy et al. 1994). A rough tongue surface, characterized by numerous dimples and fissures, facilitates tongue coating and consequently halitosis development (De Boever & Loesche 1995).

Despite only a moderate level of evidence, mechanical cleansing – which removes the obvious tongue coating – is one of the most commonly used therapeutic measures. This leads to a significant reduction of VSCs and thus a reduction of halitosis (Tonzetich & Ng 1976, Tonzetich 1978, Van der Sleen 2010, Seemann et al. 2014). This method can be enhanced by using certain chemicals, such as chlorhexidine or zinc compounds (Dadamio et al. 2013a, Dadamio et al. 2013b, Slot et al. 2015). It is also known that the VSC concentration decreases significantly during a meal and increases afterwards again (Yaegaki et al. 2012). Additionally, the VSC level is higher after a night's sleep, due to the reduced flow of saliva and the resulting increase in the bacterial load. This is referred to as "morning breath" (Tonzetich 1978).

The present authors are not aware of any scientific research from the German or English literature that describes the effects of a special high-fiber, chewing-intensive diet compared to a low-fiber, less chewing-intensive one on the concentration of VSCs, halitosis, and tongue coating. Only an opinion (not an analysis or examination) was given that foods such as hard bread, dry cereal, raw vegetables, and fibrous meat could remove tongue coating (Massler 1980). Hence, the aim of this study was to examine the effect of a one-time consumption of high-fiber, chewing-intensive food on the concentration of VSCs, halitosis, tongue coating, and the feeling in the mouth. The hypothesis was that halitosis could be reduced longer and more significantly through a chewing-intensive, high-fiber meal.

Materials and methods

The participants were 20 healthy people chosen from the regular pool of patients, as well as students and employees of the Dental Clinic of the University of Bern, who had visible tongue coating and a VSC concentration of at least 150 ppb (parts per billion) with an empty stomach in the morning. Additionally, the participants were asked to refrain from any tongue-cleansing measures and the consumption of any products containing onions or garlic two days before the screening. It was prohibited to eat, drink, or perform toothbrushing or mouthrinsing on the day of the examination. Gum and hard candy or lozenges were forbidden as well.

Exclusion criteria

Potential participants were excluded from the study if they were smokers, had allergies or intolerances to a component of the meal, had existing periodontal diseases, had suffered from diseases of the ear, nose, throat, or mouth within the last three months, or had had any serious prior or recurring disease in any of these areas. Individuals with an American Society of Anesthesiologists (ASA) classification of 3–6 (severe systemic disease to moribund state), or who had been on antibiotics within the last three weeks or had consumed foods containing onions or garlic within the last two days before the examination were also excluded.

Study design and clinical execution

The study was conducted according to a crossover design, so that every participant was part of both the test and the control group. There was a wash-out period of at least two weeks between the test and the control phase to avoid possible carry-over effects. While one half began with the test, i.e., chewing-intensive/high-fiber meal (group A), the other half started with the control, i.e., less chewing-intensive/low-fiber meal (group B).

The participants arrived at the clinic on the first day of the examination, having complied with the inclusion criteria. They were divided into the two groups by drawing lots. Afterwards, the baseline VSC concentration was measured using a Halimeter, and an organoleptic evaluation of halitosis was performed using a distance-based scale (Seemann 2006, Seemann et al. 2014). Additionally, a photo was taken of the tongue, and the participant had to indicate his/her current mouth sensation using a visual analog scale (VAS). Subsequently, the participants consumed their entire respective meal. After the meal had been ingested, the same parameters that were examined in the baseline measurement were determined again. In the ensuing 2.5 hours, the VSC concentration was measured at different intervals (Tab. I) using a Halimeter. Finally, all the parameters of the baseline and the post-ingestion measurement were determined again. For the exact time schedule of the measurements, see Table I.

Measurements with the Halimeter

The concentration of VSC was measured using a Halimeter (Interscan Corporation, Simi Valley, CA, USA). This device reacts mainly to an increase of the three major VSCs: hydrogen sulfide, methyl mercaptan, and dimethyl sulfide. Neither cadaverine, putrescine, indole nor skatole, about which there is debate as to whether or not they are involved in causing halitosis, are detected by the Halimeter. For the measurement process, a plastic straw is inserted about 3–4 cm into the patient's slightly opened mouth. The sensor is supplied with air from inside the mouth by an internal pump until a VSC maximum is reached (Rosenberg et al. 1991a).

Tab. I Procedure on examination days 1 and 2

Examination day 1		Examination day 2	
Time point	**Parameters examined**	**Time point**	**Parameters examined**
Baseline	☐ ppb VSC using the Halimeter ☐ halitosis (organoleptic) ☐ tongue coating ☐ subjective mouth sensation	Baseline	☐ ppb VSC using the Halimeter ☐ halitosis (organoleptic) ☐ tongue coating ☐ subjective mouth sensation
Subject group A: Test meal Subject group B: Control meal		**Subject group A: Control meal Subject group B: Test meal**	
Immediately after the meal	☐ ppb VSC using the Halimeter ☐ halitosis (organoleptic) ☐ tongue coating ☐ subjective mouth sensation	Immediately after the meal	☐ ppb VSC using the Halimeter ☐ halitosis (organoleptic) ☐ tongue coating ☐ subjective mouth sensation
10 min. after the meal	☐ ppb VSC using the Halimeter	10 min. after the meal	☐ ppb VSC using the Halimeter
30 min. after the meal	☐ ppb VSC using the Halimeter	30 min. after the meal	☐ ppb VSC using the Halimeter
60 min. after the meal	☐ ppb VSC using the Halimeter	60 min. after the meal	☐ ppb VSC using the Halimeter
90 min. after the meal	☐ ppb VSC using the Halimeter	90 min. after the meal	☐ ppb VSC using the Halimeter
120 min. after the meal	☐ ppb VSC using the Halimeter	120 min. after the meal	☐ ppb VSC using the Halimeter
150 min. after the meal	☐ ppb VSC using the Halimeter ☐ halitosis (organoleptic) ☐ tongue coating ☐ subjective mouth sensation	150 min. after the meal	☐ ppb VSC using the Halimeter ☐ halitosis (organoleptic) ☐ tongue coating ☐ subjective mouth sensation

ppb VSC = parts per billion volatile sulfur compounds

Organoleptic evaluation of halitosis

Organoleptic means using one's own sense of smell to perceive halitosis and to classify it according to strength (Rosenberg et al. 1991b, Greenman et al. 2014). For this study, a simple distance scale was used; the patient counts from one to ten at a normal volume, and the strength of halitosis is classified into four different degrees (Seemann 2006, Bornstein et al. 2009, Seemann et al. 2014):

- degree 0 = no halitosis detected
- degree 1 = halitosis detected at a distance of 10 cm
- degree 2 = halitosis detected at a distance of 30 cm
- degree 3 = halitosis detected at a distance of 100 cm

Evaluation of tongue coating

A modified Winkel tongue-coating index (WTCI) was used to quantify the tongue coating (Winkel et al. 2003). This index classifies the visible amount of tongue coating as a sum-score of imaginary sextants of the tongue. The modification consisted of changing the original code 2 and adding code 3. This resulted in the following evaluation system being used for each sextant:

- 0: no tongue coating
- 1: slight tongue coating
- 2: significant tongue coating in up to ⅔ of the sextant
- 3: significant tongue coating in more than ⅔ of the sextant

The evaluation was performed by two dentists familiar with the index, using photos of the tongues presented to them in a random order.

Subjective evaluation of mouth sensation

Before and after the meal, as well as at the end of the morning of examination, the participants were asked to evaluate their current mouth sensation on a VAS. The scale ranged from "very pleasant" (score 0) to "extremely unpleasant" (score 10) along 100 mm on a ruler, allowing scores to be determined to the nearest tenth.

Meals and calculation of the amount of fiber

For the meals, breakfast rolls with certain amounts of fiber were made. To precisely calculate the fiber content, the nutritional

Tab. II Meal components

	Components
Test meal (high-fiber and chewing-intensive	– 1 whole-grain bread roll (high wheat bran content) – Apple (raw, peeled) – Blackberry jam – Butter – Water
Control meal (low-fiber and less chewing-intensive)	– 1 white bread roll – Cooked apples – Quince jelly – Butter – Water

value databank of the Federal Food Safety and Veterinary Office (BLV, www.naehrwertdaten.ch) was consulted or, if available, the manufacturer's information on packaging of the individual product was used.

The different components of both of the meals are presented in Table II. The exact calculation of the amount of fiber in the foods can also be found in Table III.

Ethics

In accordance with the Helsinki Declaration, the participants were informed about the exact procedure of the study and gave their written consent, as required by the guidelines. The study was approved by the Ethics Commission of Bern (KEK-Gesuchs-Nr.: 244/12).

Statistics

The primary outcome was the percent decrease of the VSC values after a chewing-intensive, high-fiber meal and a less chewing-intensive, low-fiber meal (groups A and B).

The secondary outcome was composed of:

- seven VSC measurements over time in both groups, each in relation to the first VSC measurement
- organoleptic evaluation before and after the meal, as well as after the last VSC measurement in both groups
- determining the tongue coating index before and after the meal, as well as after the last VSC measurement in both groups
- subjective evaluation of the mouth sensation before and after the meal, as well as after the last VSC measurement in both groups

P-values <0.05 were deemed significant.

The Wilcoxon signed-rank test and a non-parametric longitudinal ANOVA by Brunner and Langer were used for the statistical analysis (Brunner et al. 2002), employing R version 3.2.2 software (The R Foundation for Statistical Computing, Vienna, Austria).

Results

All of the participants met the inclusion criteria and were admitted to the study.

When comparing the reduction of the VSC value between the first and second measurements (baseline and directly after ingesting the meal), no significant difference between the test and control group was found (Fig. 1A). The same is true of the comparison between the first and eighth measurements (baseline and at the end of the examination morning) (Fig. 1B).

Tab. III Dietary fiber content in g by product and ingredient

	Product	Ingredients	Quantity (g)	Dietary fiber (g/100 g)	Effective dietary fiber (g)
Meal A (test)	**Wheat bran bread roll**	Whole-wheat flour	34	11	3.74
		Wheat bran	37	49.3	18.24
		Water	45	0	0
		Yeast	9	6.9	0.62
		Salt	2	0	0
	Butter		unlimited	0	0
	Blackberry jam		30	4	1.2
	Apple, raw		100	2.1	2.1
					Total 25.90
Meal B (control)	**White bread roll**	White flour	75	2.5	1.88
		Milk	38	0	0
		Yeast	9	6.9	0.62
		Salt	2	0	0
	Butter		unlimited	0	0
	Quince jelly		30	0.5	0.15
	Cooked apples		100	2.76	2.76
					Total 5.41

The ingestion of a meal lowered the score of all of the examined parameters (VSC, organoleptic evaluation of halitosis, tongue coating, and subjective mouth sensation) significantly, independent of whether it was the test or the control meal ($p<0.05$). In a direct comparison, the chewing-intensive, high-fiber meal led to a statistically significantly greater reduction of the organoleptically perceptible halitosis ($p<0.05$). The other three parameters were compared directly (test vs. control meal) as well, but no significant differences were found. (Fig. 2 A–D).

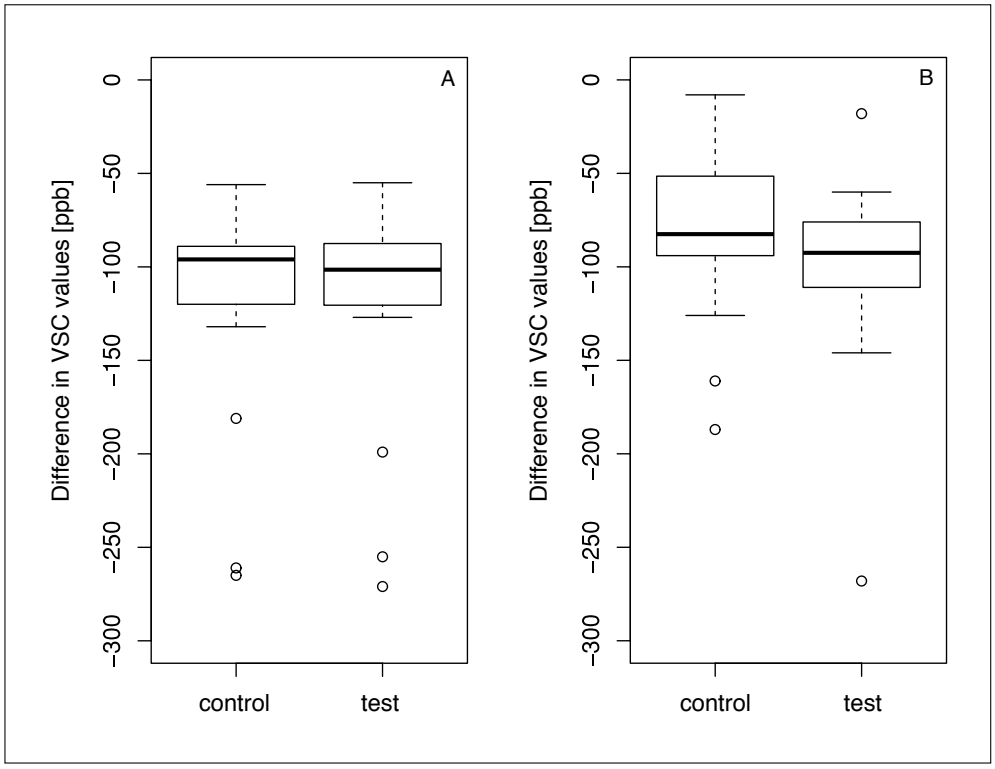

Fig. 1 Reduction of the absolute VSC values immediately after ingesting the meal compared to baseline (A), reduction of the absolute VSC values at the end of the examination morning compared to baseline (B) [ppb]

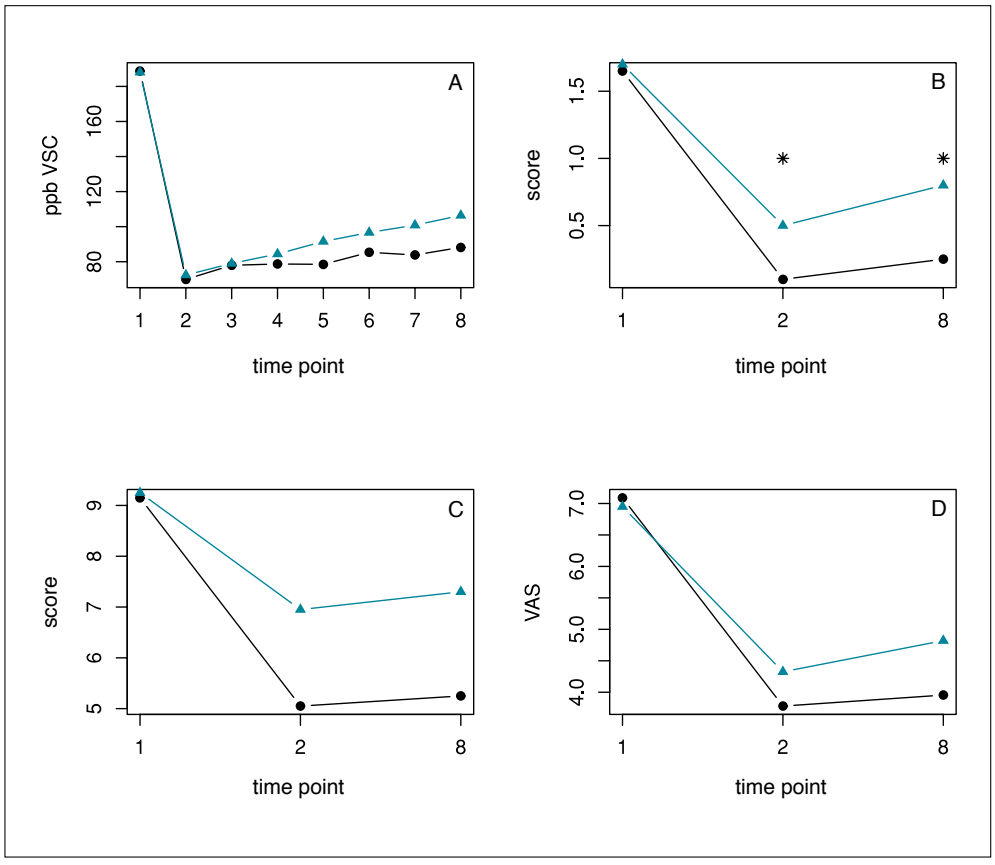

Fig. 2 (in means): Chronological sequence of the VSC measurement (A), the organoleptic halitosis measurement (B), the tongue-coating index (C), and the subjective mouth sensation (D); (* = $p<0.05$)
● = test ▲ = control

Discussion

It is the general opinion that halitosis is reduced by eating (Yaegaki et al. 2012). This effect is due to the "self-cleaning" of the mouth while chewing food. Considering the fact that the act of chewing food has a self-cleaning effect on the mouth, and thus on the dorsum of the tongue, it seems obvious that foods that need to be chewed more intensively have a stronger self-cleaning effect than foods that require less chewing. Whether foods with different chewing intensities actually influence the self-cleaning process has not yet been examined. In this study, we showed that chewing-intensive, high-fiber meals can significantly improve the organoleptic score. The study hypothesis was confirmed.

There is no universal definition for chewing intensity, chewing-intensive, or chewing-intensive foods in the literature. Thus, the term fibrous was used to describe different levels of chewing intensity. Whether or not a food is perceived as high fiber depends on the subjective assessment of the person eating it. "Fibrous", in terms of foods, refers to the dietary fibers, also called roughage. Fiber is the plant-based component in a food that cannot be digested (Suter 2008). However, the amount of fiber alone does not determine the chewing intensity of the food. An important additional factor is the consistency of the food. Concerning fruit and vegetables, the chewing intensity is influenced by whether they are consumed raw or cooked. A cooked apple, for example, has a little more fiber than a raw one, even though it is less chewing-intensive when cooked (www.naehrwertdaten.ch). Bread rolls were made especially for this study to ensure different amounts of fiber in two comparable products.

The present results confirmed that eating a meal reduces oral VSC concentrations and halitosis (Fig. 1A and B, Fig. 2B). There was a statistically significant improvement of the subjective mouth sensation and reduction of the tongue coating in both groups (Fig. 2D and C). Even after 2.5 hours, this effect could still be measured. However, comparing the effect of foods with different levels of chewing intensity, no consistent pattern was found in this study. Hence, the effects of chewing-intensive, high-fiber foods should be observed over a longer period of time in a follow-up study. While there was no statistically significant difference for the oral VSC, tongue coating, or subjective mouth sensation between the test and the control groups, the organoleptic evaluation of halitosis showed a statistically significantly greater reduction in the test group. The non-significant differences could be explained by the insufficient sample size of this pilot study. In a potential follow-up study, the sample size should be increased. Another reason could be that the chewing intensities of the two meals were too similar, despite the extremely different amounts of fiber. Both types of bread roll required thorough chewing; therefore, any future examinations should compare foods requiring little to no chewing, such as yoghurt or soup. It must also be discussed whether or not the Halimeter, despite its acceptable reproducibility, is capable of detecting minor differences, because the concentration of different sulfur compounds collectively determine the VSC value (in ppb) (Rosenberg et al. 1991b). Gas chromatographic measurements should be considered for future studies. However, this type of measurement also has certain problems, e.g., the difficulties of standardized sample taking or not being able to provide real-time measurements, which are possible with a Halimeter (Rosenberg et al. 1991a, Lalemann et al. 2014). Because this study compares the relative differences rather than the absolute VSC values, and numerous measurements were made within relatively short period of time, using the Halimeter was justified.

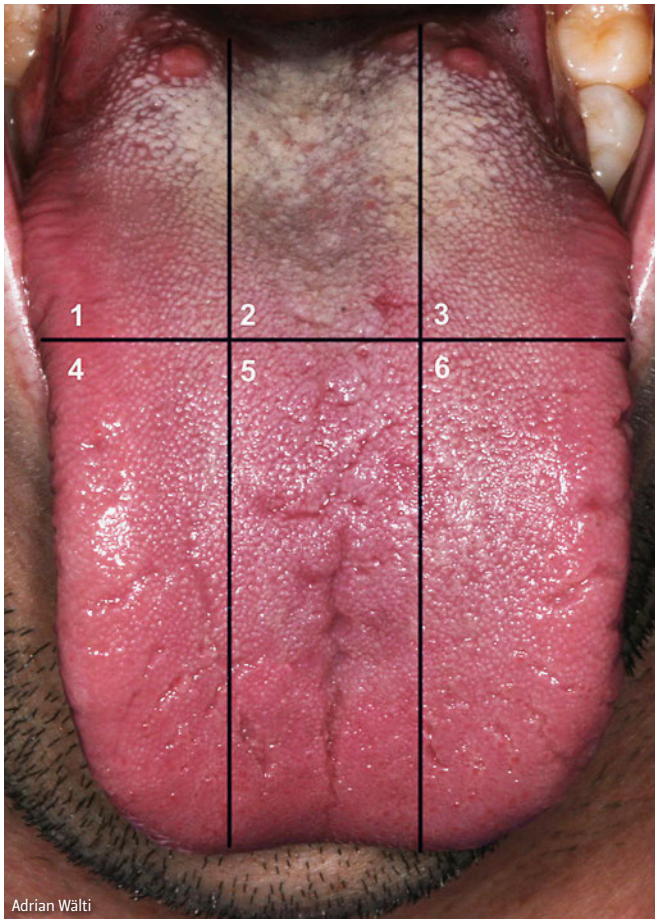

Fig. 3 Division of the dorsum of the tongue into sextants to determine the modified Winkel tongue-coating index

The non-significant parameters also tended to show a greater reduction after eating the test meal. Thus, we conclude that chewing-intensive, high-fiber foods reduce oral halitosis more than less chewing-intensive, low-fiber foods. The slight effect observed due to the choice of foods could also be seen in the evaluation of the tongue coating. Therefore, it was necessary to modify the Winkel tongue-coating index in order to increase its sensitivity. Nonetheless, there was no significant difference between the test and the control phase. The sensitivity of the tongue-coating index was increased by adding an additional score, resulting in the modified Winkel tongue-coating index (mWTCI). An example is given in figure 3. Using the original index (0 = no coating; 1 = slight coating; 2 = significant coating), the results would have been as follows: 2/2/2/0/0/0; sum = 6. Even though the amount of tongue coating in sextants 1 and 3 appear to differ from the amount in sextant 2 on the photos, this difference could not be described by the index. By applying the modified index (0 = no coating; 1 = slight coating; 2 = significant coating in up to ⅔ of the sextant, 3 = significant coating in more than ⅔ of the sextant), the difference is quantifiable (2/3/2/0/0/0; sum = 7). While the original index may be sufficient for the dental praxis, we recommend making appropriate modifications in clinical studies to increas its precision.

Conclusion

In conclusion, it can be said that ingesting the meals chosen in this study reduces oral halitosis for at least 2.5 hours. A direct comparison of the two meals showed that, the chewing-intensive, high-fiber meal led to a greater reduction of halitosis ($p<0.05$).

Résumé

Le dépôt bactérien sur la langue est la cause la plus fréquente de l'halitose orale et manger conduit à sa réduction. L'influence des différents aliments sur le dépôt bactérien lingual et l'halitose est jusqu'alors peu étudiée. Le but de cette étude était donc de comparer l'effet de la nourriture riche en fibres alimentaires par rapport à la nourriture faible en fibres alimentaires après une consommation unique quant aux paramètres de l'halitose.

A l'aide d'une étude clinique randomisée croisée, 20 participants ont été examinés sur une période de 2,5 heures après l'ingestion d'un repas riche en fibres alimentaires, respectivement faible en fibres alimentaires. La détermination des composés soufrés volatils (VSC = volatile sulphur compounds) a été réalisée en utilisant un Halimeter et l'appréciation organoleptique d'un indice sur la distance. Le dépôt bactérien sur la langue a été déterminé en utilisant l'indice de Winkel, la sensation en bouche a été subjectivement évaluée par les participants.

Indépendamment du repas consommé, une réduction statistiquement signifiante dans tous les paramètres mesurés a pu être détecté ($p<0,05$). Une comparaison directe des repas (faible en fibres/riche en fibres) a montré une réduction statistiquement signifiante seulement pour l'appréciation organoleptique ($p<0,05$).

En résumé, nous pouvons conclure que la consommation des repas sélectionnés dans cette étude a abouti à une réduction d'une halitose orale d'au moins 2,5 heures. Le repas plus intense à mâcher (riche en fibres) a abouti à une réduction plus forte de l'halitose orale ($p<0,05$).

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