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Villa A, Zollanvari A, Alterovitz G, Cagetti MG, Strohmenger L, Abati S. Influence of different toothpaste abrasives on the bristle end-rounding quality of toothbrushes.

Prevalence of halitosis in children considering oral hygiene, gender and age

Abstract: *Background:* To date, few studies have addressed halitosis in the paediatric population. As such, the aim of the present study was to investigate symptoms, signs and risk factors associated with halitosis in healthy children and to present a model based on the clinical data that predicts the presence of halitosis. *Methods:* A total of 101 individuals were included. All patients received a questionnaire that queried on sociodemographic characteristics, self-reported halitosis and dental treatment history. Individuals received a thorough intra-oral examination, and the volatile sulphur compounds (VSC) were measured to test the presence of halitosis with a portable sulphide monitor (Halimeter®; Interscan Co., Chatsworth, CA, USA). The distribution of the sociodemographic characteristics, self-reported halitosis, dental treatment history and other oral features was evaluated. Finally, a statistical model was constructed with the best set of features to predict halitosis in children. *Results:* The median age was 12.0 years (mean: 11.7 ± SD 2.7) with 54.5% males. Halitosis (VSC > 100 parts per billion, or ppb) was objectively measured in 37.6% of patients. For comparison purposes, Bayesian network was obtained using clinical and demographic data. The model consisted of four variables (sex, age, oral hygiene status and self-reported halitosis) directly related to the presence of halitosis (VSC > 100 ppb). This model achieved 76.4% area under receiver operating characteristics curve (AUROC). Overall, female patients or individuals with dental plaque on more than 25% of the dental surfaces or patients older than 13 year old were more prone to present with halitosis. *Conclusions:* The results suggest that halitosis in the paediatric population is related to poor oral hygiene and may be more common in females and older individuals. This specific predictive model may be useful to identify subgroups to target for intervention to treat oral halitosis.

Key words: children; halitosis; prediction

Introduction

Halitosis is a common unpleasant condition that affects many individuals of all ages and may cause important social and psychological barriers (1, 2). Around 85% of the bad breath arises in the mouth (3, 4), with the remainder originating from respiratory tract infections or systemic disorders, such as hepatic cirrhosis, poorly controlled diabetes mellitus and kidney disease (5). Halitosis as the result of gastrointestinal disorders is considered to be rare (6).

Plaque retention and poor oral hygiene commonly give rise to halitosis due to microbial putrefaction by oral microorganisms and other bacteria that produce volatile sulphur compounds (VSCs) such as hydrogen sulphide (H_2S), methyl mercaptan (CH_3SH) and dimethyl sulphide [$(CH_3)_2S$] (7). It has been shown that patients wearing orthodontic appliances are more prone to accumulate bacterial plaque (8, 9). Orthodontic appliances could act as a potential plaque retentive source (10) and thus promoting halitosis.

Although halitosis is a common complaint in the adult population, also children may be affected by this unpleasant condition. Lin *et al.* (11) evaluated the correlation of halitosis (VSC > 100 ppb) in 30 children and 18 mothers. The authors found halitosis in 23% of children and 11% of mothers, but it was not significantly correlated. Overall, to date, few studies have addressed this phenomenon in the paediatric population and the majority of the papers focus on halitosis secondary to upper respiratory tract infections (12, 13). In addition, there are no available data on the prediction of bad breath in children. As such, the aim of the present study was to (i) investigate the prevalence, symptoms, signs and risk factors associated with halitosis in healthy children and (ii) to present a model (naïve Bayesian network) based on the clinical data that predicts the presence of halitosis.

Study population and methods

Study population

Children were recruited among young attendees of the Dental Clinic of the University of Milano, Italy. All participants, parents or guardians gave written informed consent. This study was approved the by the scientific board of the dental clinic. The study population consisted of people who met the following eligibility criteria: (i) ages 6–16 years, (ii) good general health and (iii) willing to comply with the study protocol. Patients with caries or on medications were excluded for the purpose of this study.

Data collection

At the first appointment, all patients received the same questionnaire in the waiting room of the dental clinic; the questionnaires were self-administered, yet a parent or guardian was available to help their children. The questionnaire queried on sociodemographic characteristics, self-reported halitosis (14) and dental treatment history. Participants were told to abstain from eating strong-smelling foods in the 48-h period before the second visit (15). At the second visit, all patients received a comprehensive orthodontic and clinical examination. A trained clinician collected the following parameters during the visit: (i) plaque index, (ii) Angle class (16), (iii) breathing habits and (iv) tonsil size. The plaque index was calculated using the Silness–Löe plaque index (PI) on six index teeth (17). The average value of all tooth surfaces was recorded as the plaque index score. Tonsil size was graded as suggested by Brodsky (18, 19) (0 = no enlargement; 1 = tonsils occupy less than half of the transverse diameter of oropharynx; 2, 3 and 4 = tonsils are even bigger than in the previous case).

The measurements of intra-oral VSCs were performed with a portable sulphide monitor (Halimeter®; Interscan Co., Chatsworth, CA, USA). Oral VSCs are measured by an electrochemical sensor using a suction pump to bring mouth air into the instrument. Subjects had to close their mouth for 120–180 s before sampling. Samples were collected by the use of a disposable plastic straw inserted deep into the oral cavity; the mouth was kept open by approximately 1.5 cm, and the peak value from three subsequent measurements was recorded (20). The measurement of the concentrations of VSC took about 15 s and was expressed in parts per billion (ppb). Halitosis was defined as having ppb > 100 (3, 11). The organoleptic score was assessed on a 0–5 scale by a trained odour judge (21).

Statistical analysis

The distribution of the sociodemographic characteristics, self-reported halitosis, dental treatment history and other oral features was evaluated. For the purpose of this analysis using plaque index, we created a trichotomous variable (plaque not present, plaque present in at least 25% of dental sites and plaque present in <25% of dental sites) to assess oral hygiene level in the study sample. We used median of age (12 years old) to dichotomize this variable for possible consideration in the constructed model. We did not consider more levels for age variable to reduce the search dimensionality space for finding the best possible model using the limited number of data in the study. We used an exhaustive search combined with a wrapper feature selection procedure to select the best contributing set of features of 11 features described in Table 2. The selected classification rule was an external 10-fold cross-validation as described by Dupuy *et al.* (22) combined with naïve Bayesian classifier with an internal 10-fold cross-validation (CV) evaluator of each feature set. In this procedure, we split the data to 10-folds, and on each time, we consider ninefolds in feature selection procedure. To evaluate the predictive power of every possible feature sets ($2^{11} = 2048$ feature sets), a so-called internal 10-fold cross-validation combined with naïve Bayesian classifier is used. The best set of features in the final model constructed on the full dataset is selected to be the union of all features that appear more than a predetermined number of times among the best set of features selected in every repetition of 10-fold CV. Here, we selected this predetermined number to be six or higher. Finally, we constructed a naïve Bayesian network with this best set of features selected from the aforementioned strategy.

Results

A total of 101 individuals were included in this study. Patients aged from 6 to 16 years were ranged; the median age was 12.0 years (IQR: 10.0–14.0; mean: 11.7 ± SD 2.7) and 54.5% were males (Table 1). Halitosis was reported by 42.6% of

Table 1. **Sociodemographic characteristics, oral features and oral malodour**

	Total (n = 101) n (%)
Gender	
Female	46 (45.5)
Male	55 (54.5)
Age category	
6–12	44 (43.6)
13–16	57 (56.4)
Median [IQR]	12 [10.0–14.0]
Mean ± SD	11.7 ± 2.7
Antibiotic in the last month	
No	94 (93.1)
Yes	7 (6.9)
Oral hygiene status	
No plaque (score 0)	40 (39.6)
Plaque <25% (score 1)	48 (47.5)
Plaque >25% (score 2)	13 (12.9)
Mean plaque score	0.7 ± 0.7
Angle class	
I	34 (33.7)
II	34 (33.7)
III	33 (32.6)
Bite	
Normal	42 (41.6)
Deep	47 (46.5)
Open	12 (11.9)
Any orthodontic appliance	68 (67.3)
Fixed orthodontic appliance	54 (53.5)
Mobile orthodontics appliance	14 (13.9)
Breath	
Nasal	66 (65.4)
Oral	5 (4.9)
Mixed	30 (29.7)
Tonsils	
0	74 (73.3)
Brodsky > 1	27 (26.7)
Self-reported halitosis	
No	58 (57.4)
Yes	43 (42.6)
VSC > 100 ppb	
No	63 (62.4)
Yes	38 (37.6)
Mean ± SD	115.6 ± 108
Organoleptic test	
0	55 (54.5)
1	31 (30.7)
2	15 (14.8)
3 or more	0 (0.0)
Mean ± SD	0.6 ± 0.7

Abbreviations: IQR, intraquartile range; SD, standard deviation; VSC, volatile sulphur compounds; and ppb, parts per billion.

Table 2. **List of all attributes used in the predictive models for oral malodour (VSC > 100 ppb)**

	Halitosis (VSC > 100 ppb)	
	Yes n (%)	No n (%)
Age category		
6–12	12 (32.1)	32 (50.8)
13–16	26 (67.9)	31 (49.2)
Gender		
Female	22 (57.9)	24 (38.1)
Male	16 (42.1)	39 (61.9)
Oral hygiene status		
No plaque	9 (23.7)	31 (49.2)
Plaque <25%	21 (55.3)	27 (42.9)
Plaque >25%	8 (21.1)	5 (7.9)
Self-reported halitosis		
Yes	21 (55.3)	22 (34.9)
No	17 (44.7)	41 (65.1)
Females (13–16) with plaque >25%	10 (76.9)	3 (23.1)
Males (13–16), with plaque <25%	8 (29.6)	19 (70.4)

participants. When oral hygiene was considered, 39.6% of the individuals did not have any dental plaque deposits, 12.9% presented dental plaque on more than 25% of the dental surfaces examined, and 47.5% of patients had <25% surfaces with plaque.

Orthodontic features such as Angle class and open bite are reported in Table 1. A total of 67.3% of the patients wore an orthodontic appliance at the time of the visit (53.5% fixed and 13.9% mobile). The majority of the individuals had nasal breath (65.4%) and 26.7% had a tonsil size >1 (Brodsky scale). Halitosis (VSC > 100 ppb) was present in 37.6% of patients (mean: 115.6 ppb ± SD 108 ppb). Approximately 62% of patients had the absence of odour.

For comparison purposes, we then obtained a Bayesian network using the clinical and demographic data. The model consisted of four variables directly related to the presence of halitosis (VSC > 100); there were no other connections. The following features were included: sex, age, oral hygiene status and self-reported halitosis. Around 51% of the patients with halitosis (VSC > 100 ppb) were under the age of twelve, 61.9% were males, and 50.8% had dental plaque (Table 2). Our model achieved 76.4% area under receiver operating characteristics curve (AUROC). We validated our results in a different population by predicting the occurrence of halitosis in thirty individuals not included in the original study. Our model achieved the AUROC of 75.4% on this test set, which included 19 individuals without halitosis and 11 individuals with halitosis. Overall, female patients or individuals with dental plaque on more than 25% of the dental surfaces or patients older than 13 year old were more prone to present with halitosis.

Discussion

The purpose of the present study is to identify predictive factors for halitosis in a group of healthy children presenting for a routine orthodontic check-up, using a self-administered questionnaire, objective odour judge and instrumental measurements. Our findings show that halitosis was present in approximately 38% of the individuals. This is in agreement with the large majority of studies that report that about 30–50% of people have halitosis (23). However, the real prevalence of halitosis remains unclear due to heterogeneity of the

studies and because many papers are based only on subjective self-estimation (24).

Using Bayesian networks, we identified four predictors of halitosis: oral hygiene level, self-reported halitosis, sex and age. This network is presented in Table 2. Bayesian networks are an innovative approach developed at the crossroads of statistics and artificial intelligence. Most recently this has been used in clinical settings and has great performance in medical diagnosis. The Bayesian ranks alternative models of associations on the basis of their posterior probability.

Around 12% of the children included in this analysis presented with dental plaque on more than 25% of the dental surfaces examined. Bad oral hygiene has been associated with halitosis in the adult population. Similarly, a recent study by Nalcaci and colleagues (25) showed that children with poor oral hygiene and dental plaque had a significant increase in the odds of detecting halitosis. Another study conducted on 24 healthy children confirmed that halitosis was significantly associated with plaque index levels ($r = 0.64$, $P = 0.001$) (26).

To our knowledge, there are no studies that investigated the correlation between self-report halitosis and objective halitosis in younger patients. Of note, two studies considered parents complaining of the bad breath of their children (25, 27). Several studies show that self-estimation of halitosis is correlated with the presence of halitosis as determined by organoleptic examinations. However, this association is still controversial (28, 29). Interestingly, self-reported halitosis in our study was a good predictor for halitosis, suggesting a potential role in the diagnosis of objective halitosis.

Patients older than 13 year old were more prone to have VSC > 100 ppb, thus presenting with halitosis. This is in agreement with previous studies that showed that increasing age might be associated with an increasing prevalence of halitosis (30–32). Older individuals have a different diet and habit (e.g. tobacco smoking and alcohol consumption) that may contribute to the development of halitosis (24).

Our findings suggest that being a female is a predictor for having halitosis. This is in contrast with a recent large Brazilian study that showed that the prevalence of persistent halitosis was nearly three times higher in men than in women (30). It may be that female patients had more dental plaque when compared to males, thus developing more halitosis. Another possibility is that older females (>13 year old) presented with halitosis secondary to the sex hormones storm in pubertal age (33).

The study has several limitations. First, the sample size is small and the model needs validation in a larger number of subjects, an area of future research. Second, larger studies with randomly selected population are needed for the results to be applicable to the general population. Third, we did not control for necrotic teeth, impacted deciduous teeth or mobile deciduous teeth and recent dental treatment, as all these factors might have affected the level of halitosis. Despite these limitations, however, this specific predictive model may be useful to identify subgroups to target for intervention to treat oral halitosis. Paediatricians and dentists may ask little patients if they report self-halitosis and with an oral examination and demographic data identify groups for halitosis. As such, patients with suspected halitosis may be referred to a paediatric dentist for further evaluation and management.

In summary, halitosis in the paediatric population is a common condition (38%) and may be identified using this predictive model. Preventative strategies for older females with poor oral hygiene may be implemented to reduce the prevalence of oral halitosis in these patients. Healthcare professionals should educate their young patients to further improve oral hygiene conditions, thus reducing the risk of halitosis. Oral healthcare professionals have the unique opportunity to address fresh breath concerns with patients and educate them on the available treatments for halitosis.

Clinical relevance

Little is known on halitosis in the paediatric population, and few tools are available to predict the presence of bad breath in the population. As such, the prevalence of halitosis in young patients was analysed and a predictive model for halitosis was built. These findings showed that halitosis was present in around 40% of children. A new predictive model of clinical utility showed that sex, age, oral hygiene status and self-reported halitosis were good predictors for halitosis in children. This tool may be used by the clinician to identify individuals at risk of developing halitosis.

Conflict of interest and sources of funding statements

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