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CLASSIFICATION TREE METHOD FOR DETERMINING FACTORS ASSOCIATED WITH HALITOSIS

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Abstract: Decision trees are data mining techniques for extracting hidden knowledge from large databases. This study was performed to establish the risk factors associated with halitosis by applying a decision tree model in a Turkish population and examining the interactions between these factors. We obtained data from a total of 1.290 patients, consisting of 645 patients with halitosis and 645 healthy controls. The subjects' demographic characteristics, smoking status, alcohol intake, medical history and medications were assessed. The presence of potential intraoral causes of halitosis was determined by investigating perceived oral health problems such as caries, periodontal diseases, tongue coating, and oral cavity pathologies. Halitosis level was evaluated using an organoleptic scale. All data were subjected to classification tree analyses. Halitosis was significantly more common in patients with (80.9%) than without (20.7%) oral health problems ($P < 0.001$). Halitosis was significantly less common in non-smokers without oral health problems than in smokers with oral health problems (14.5%; $P < .001$). Halitosis was evident in all patients with oral health problems, smokers, and those with respiratory diseases (100%). The effects of systemic diseases on halitosis were significant in non-smokers without oral health problems ($P < 0.05$). Respiratory conditions showed significant effects on halitosis in smokers with oral health problems ($P < 0.01$). We developed a decision tree model to identify risk factors associated with halitosis. The classification tree method showed that the most significant factors affecting halitosis were oral health problems followed by smoking status.

Keywords: Halitosis, Bad breath, Classification tree method, Data mining, Decision tree, Causes

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1. Introduction

Halitosis, also known as oral malodour or bad breath, is defined as an unpleasant or offensive odour emanating from the mouth and breath that is noticed by others (Kapoor et al., 2016). It is divided into three categories (i.e., genuine halitosis, pseudo-halitosis, and halitophobia) (Murata et al., 2002). A diagnosis of genuine halitosis is made in cases in which obvious malodour with intensity beyond the socially acceptable level is perceived and can be treated with methods that eliminate the etiological factors such as poor oral hygiene, periodontal diseases, or systemic conditions. Patients who complain of halitosis but who have no obvious malodour perceptible to others are diagnosed with pseudo-halitosis. A diagnosis of halitophobia is made in patients who still believe that they have bad breath after treatment of either genuine or pseudo-halitosis; such patients are referred to a mental health specialist for effective management (Van den Broek et al., 2007).

The causes of halitosis are multifactorial (Rösing et al., 2015; Oyetola et al., 2016), and with both oral and non-oral factors as sources (Eldarrat, 2016). The oral sources of halitosis include necrotic pulpal exposure, deep carious lesions, food impaction, oral infections, periodontal diseases, faulty restorations, unclean dentures, reduced salivary flow, and poor oral hygiene including not brushing and flossing (Van den Broek et al., 2007; Cortelli et al., 2008; Nazir et al., 2017). The non-oral sources of halitosis are poor eating habits and systemic diseases such as respiratory and gastrointestinal conditions, some metabolic diseases, carcinomas, and certain medications (Van den Broek et al., 2007; Nazir et al., 2017). Co-factors that facilitate halitosis include stress, reduced quantities of saliva, smoking, high coffee consumption, and onions, garlic, and spicy food (Schumacher et al., 2017).

It is important to manage or control halitosis, as oral malodour can have negative effects on quality of life and human relationships. Diagnosis of halitosis requires a series of systematic steps including medical history taking, halitosis-specific questionnaire, clinical examination, and specific tests to assess/quantify the problem (Codinach and Salas, 2010). There are different subjective and objective methods for determining the presence of halitosis, with the organoleptic test considered the gold standard. However, several systems have been designed to objectively determine the presence of the volatile sulphur compounds responsible for halitosis including sulphide monitors, gas chromatography, and the BANA test (N-benzoyl-DL-arginine-2-naphthylamide). Treatment of halitosis involves the identification and elimination of the underlying cause, if possible the reported prevalence of halitosis ranges from 14% to >50% in different populations (Zhang et al., 2016). The incidence of halitosis is reportedly about 28% in Turkish individuals >60 years old (Nalcaci and Baran, 2008). Bad breath is a universal problem in both sexes and in all age groups in different cultures and societies (Nalcaci and Baran, 2008).

Data mining is a retrospective computational method for extracting knowledge from large databases. It involves many different algorithms for performing different tasks, all of which attempt to identify a model that best describes the properties of the data being examined. Different algorithms are used in data mining procedures including traditional statistical methods (e.g., linear regression analyses), neural networks, association rule mining, and decision trees (Kurt et al., 2008; Alizadehsani et al., 2013; Tayefi et al., 2017a; Tayefi et al., 2017b). The data mining technique, Classification and Regression Tree (CART) analysis, is an innovative and powerful statistical technique with significant clinical utility. CART analyses use a decision tree to classify data. As the trees are clear and easy to interpret, CART is widely used in medicine(D'Alisa et al., 2006; Kurt et al., 2008; Alizadehsani et al., 2013; Barlin et al., 2013: Patel et al., 2014; Zimmerman et al., 2016; Tayefi et al., 2017a; Tayefi et al., 2017b), biology (Vayssières et al., 2000) and psychology (Rosenfeld et al., 2005). In addition, the CART technique has recently been used in dentistry (Ito et al., 2011; Arino et al., 2016; Machuca et al., 2017).

This study investigated the risk factors associated with halitosis by applying a decision tree model in a Turkish population and examined the interactions between these factors. These results will be useful for identifying patients at increased risk for halitosis.

2. Material and Methods

This study included 645 patients who attended the clinic complaining about bad breath, and 645 healthy controls were selected among people who attended clinics for routine dental assessment. The subjects with halitosis were patients who presented to our Oral Diagnosis clinic because of halitosis or perceived halitosis. We obtained data from a total of 1290 patients. Patients who complained of bad breath or those with perceivable halitosis on clinical examination were included in the study. Patients <18 years and those who did not provide consent were excluded from the study. The healthy subjects had no halitosis and none of the non-oral risk factors for halitosis such as respiratory and gastrointestinal conditions, metabolic diseases, carcinomas, and certain medications. Subjects >18 years old, who provided consent, and were not pregnant or breastfeeding, were included in the healthy control group. The subjects' oral health status and halitosis levels were assessed. Assessment of oral health status included dental caries, periodontal status, dental plaque, oral cavity pathologies, dental crowding, tongue coating, and prosthetic factors, such as non-cleaning of the dental bridge body, keeping dentures in at night or not regularly cleaning dentures and poorly adapted restorative crowns. Halitosis levels were assessed using the organoleptic scale established by Rosenberg et al. (1992). This scale ranges from 0 to 5, where 0 represents no oral alodour; 1, barely noticeable odour; 2, slight but clearly noticeable odour; 3, moderate odour; 4, strong odour; and 5, extremely strong odour. Scores of 0 and 1 were assigned to the group with normal odour/no presence of halitosis (healthy controls), and individuals with a score ≥2 were assigned to the group with malodour/presence of halitosis. In addition, medical history and medications related to oral health and halitosis, smoking status and demographic factors (age, sex) were also investigated and noted.

The classification tree method allows visualization of discrete dependent variables and the relationships between independent and dependent variables through visual nodes (Yamauchi et al., 2001; Chang et al. 2006; Hebert et al., 2006). The initial node, called the root node, is the most heterogeneous. The following nodes (child nodes) are more homogenous compared to the root node, with the terminal node being the most homogenous (Camdeviren et al., 2007). Establishment of the classification tree begins from the root node, which completely includes all dependent and independent variables. The aim of the tree is to separate the terminal node from child nodes homogeneously at the highest level, and to exclude those variables that are not related to the dependent variable. This latter processing is called splitting. We used the classification tree method to evaluate the effects of independent variables on halitosis and the effects of interactions effects among the factors.

The growth method featured chi-square automatic interaction detection to identify the independent (predictor) variable exhibiting the strongest interaction with the dependent variable. The algorithm selects a set of predictors, examines their interactions, and predicts the optimal value of the dependent variable, eventually creating a classification tree. All statistical analyses were performed using SPSS ver. 15.0 for Windows. $P < 0.05$

was taken to indicate statistical significance.

2.1. Ethical Consideration

This study was approved by the Human Ethics Committee (Approval No. 2018/4-22) and was performed in accordance with the Declaration of Helsinki.

3. Results

The descriptive statistics of halitosis in accordance with oral health problems, smoking, systemic diseases, respiratory problems, sex, age, alcohol intake, gastrointestinal conditions and medications are given in Table 1. The structure of the optimum tree is shown in Figure 1.

Table 1. Descriptive statistics and the effects of various factors on halitosis

	Group			
	Halitosis		Control	
	n	%	n	%
	645	50	645	50
Risk factor	Yes		No	
Oral Health problems	627	48.6	663	51.4
Smoking status	402	31.2	888	68.8
Alcohol intake	171	13.3	1119	86.7
Medications	190	14.7	1100	85.3
Respiratory diseases	1075	83.3	215	16.7
Gastrointestinal diseases	150	11.6	1140	88.4
Systemic diseases	388	30.1	902	69.9
	Mean	SD	Mean	SD
Age	35.06	11.56	34.72	12.35
Sex	Female		Male	
	n	%	n	%
	599	46.4	691	53.6

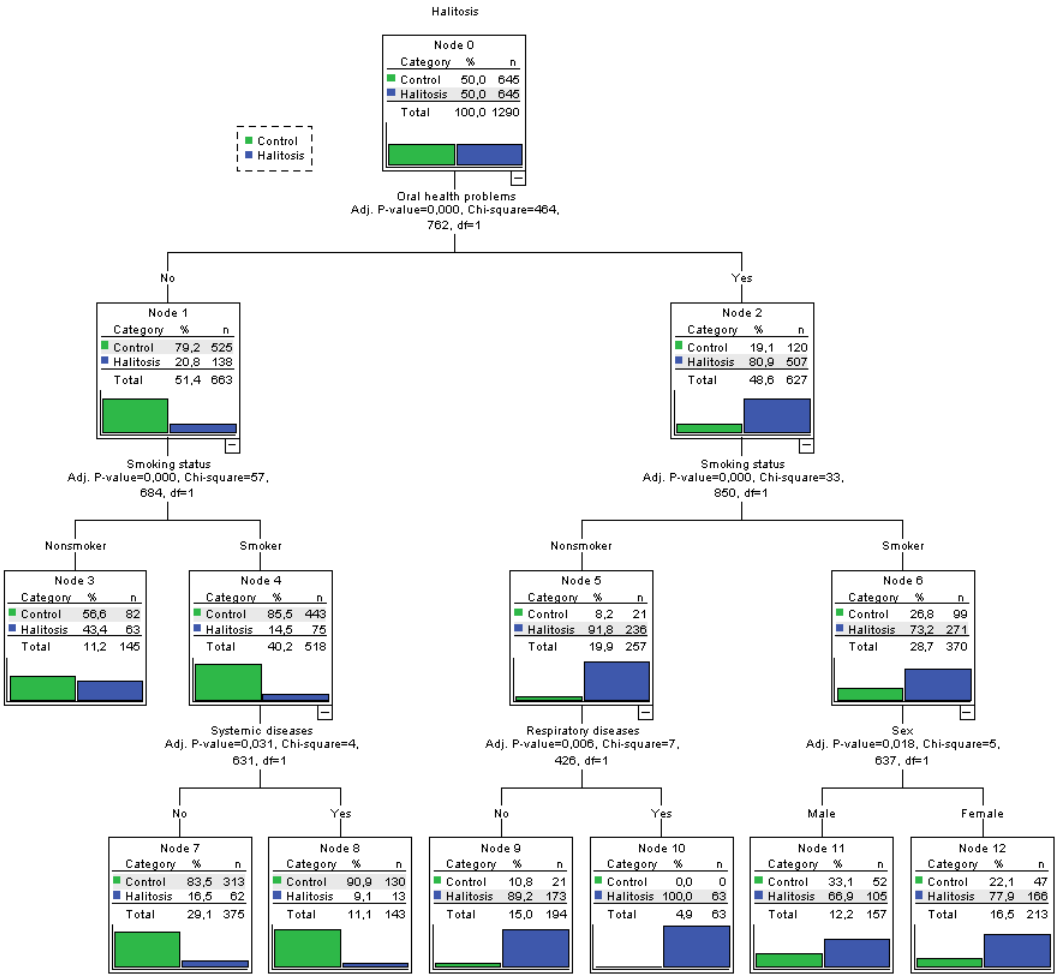

Figure 1. Optimal regression tree.

The optimal tree shows the predictions of halitosis using the variables including oral health problems, smoking, systemic diseases, respiratory problems, and sex. The root node (Node 0) contained descriptive halitosis statistics, which was the most heterogeneous node (Figure 1). Oral health problems, smoking, systemic diseases, respiratory problems and sex were significantly associated with the incidence of halitosis ($P < 0.001$). Oral health problems represented the most significant factor, and thus constituted the terminal node. The other factors formed child nodes in which oral health problems were either present or absent. The rate of halitosis was significantly higher in patients with oral health problems (Node 2, 80.9%) than in those without oral health problems (Node 1, 20.8%) ($P < 0.001$). The rate of halitosis was highest in patients who smoked and had oral health problems (Node 5, 91.8%), whereas it was significantly less common in non-smokers without oral health problems (Node 4, 14.5%) ($P < 0.001$). In non-smokers without oral health problems, the effects of systemic diseases on halitosis were significant ($P < 0.05$). Interestingly, the rate of halitosis was higher in patients without systemic diseases (Node 7, 16.5%) than in patients with systemic diseases (Node 8, 9.1%). The effects of sex on halitosis were significant among non-smokers with oral health problems ($P < 0.05$). The rate of halitosis was higher in females (Node 12, 77.9%) and lower in males (Node 11, 66.9%). In smokers with oral health problems, the effects of respiratory conditions on halitosis were significant ($P < 0.01$). Halitosis was detected in 100% of patients with respiratory conditions (Node 10), and it was more common in those without such respiratory conditions (Node 9; 89.2%).

4. Discussion

Halitosis is a common health problem with significant psychological and social effects. Therefore, increasing numbers of patients with halitosis visit dental clinics. Dentists play important roles in the diagnosis and treatment of halitosis and in the referral of patients to a physician or medical specialist if necessary. There have been several studies during the last decade regarding the prevalence and factors associated with halitosis in diverse populations such as white collar employees, adults, university students, young mothers, the elderly, army recruits, high school students, and adolescents (Nalcaci et al., 2008; Bornstein et al., 2009; Yokoyama et al., 2010; AlSadhan et al., 2016; Chen et al., 2016; Eldarrat et al., 2016).

Recently, the use of decision tree methods in medicine and biology has become increasingly common (Vayssières et al., 2000; Fonarow et al., 2005; D'Alisa et al., 2006; Barlin et al., 2013; Patel et al., 2014; Zimmerman et al., 2016) For example, classification trees have been used in medicine for the diagnosis of a medical condition from the pattern of symptoms, in which the classes defined by the decision tree could either be different clinical subtypes of a condition, or in determining which patients with a condition should receive different therapies (Song et al., 2015). Unfortunately, there have been few reports of the use of decision tree algorithms in the field of dentistry (Ito et al., 2011; Arino et al., 2016; Machuca et al., 2017).

In this study, we constructed a decision tree based on data from a cross-sectional study to investigate the associated risk factors for halitosis. We performed data mining analyses using a decision tree algorithm in 1.290 patients including nine major risk factors of halitosis. Among the risk factors of halitosis, oral health problems, smoking, systemic diseases, respiratory problems and sex were entered into the algorithm, whereas age, alcohol intake, gastrointestinal conditions, and medications were not considered because they showed no significant differences between healthy controls and patients with halitosis. The major factors related to halitosis were oral health problems and smoking.

The node generated by oral health problems is called the terminal node, and this node is closest to the root node. The terminal node had a slightly more homogenous structure and was separated into two different nodes (Node 1 and Node 2). The highest rate of halitosis (80.9%) was evident in patients with oral health problems (Node 2), and was significantly greater than that (25.3%) in patients without oral health problems (Node 1). Oral health problems such as periodontal diseases, tongue coating, open caries lesions, poor oral hygiene, local infections such as pericoronitis and peri-implantitis, or various combinations of these factors, have been considered important in the onset of halitosis. Most clinicians agree that the oral cavity is the main source of halitosis in the majority of cases (80–90%) (Bollen and Beikler, 2012; Eldarrat, 2016). Söder et al. (2007) reported that halitosis was correlated with oral hygiene and dental visits, and that periodontitis patients with halitosis had more severe disease than those without halitosis. Chen et al. (2011) reported that halitosis was significantly related to tongue coating thickness and periodontal pocket depth. A systemic review of the intraoral and extraoral causes of halitosis reported that the aetiology of halitosis is complex, but tongue coating and periodontal diseases are the main aetiological factors (Codinach et al., 2014). Moreover, age, prevalence and severity of dental caries are significantly related to halitosis (Nalçaci et al., 2008).

There are co-factors that significantly influence halitosis including smoking, coffee or alcohol consumption reduced salivary flow rate, stress, mouth breathing, an unbalanced diet, and low daily amount of water (Christen et al., 1992; Rosenberg et al., 2007; Van den Broek et al., 2007). The possible relationships between smoking and otorhinolaryngological symptoms in smokers, non-smokers, and ex-smokers were investigated by Şanlı et al. (2016). In this study, the rate of bad breath was significantly higher in current smokers that in non-smokers and ex-smokers (Şanlı et al. 2016). Jiun et al. (2015) reported an association between oral hygiene

status and halitosis among smokers and non-smokers; halitosis and volatile sulphur compound levels were significantly higher among smokers than non-smokers. In this study, smoking status was significantly associated with the incidence of halitosis, which was 43.4% in smokers lacking oral health problems (Node 3) and 91.8% in smokers with oral health problems (Node 5).

Extra-oral sources of halitosis include respiratory, gastrointestinal and metabolic conditions (Scully and Greenman, 2012). In addition, drugs and psychogenic or psychosomatic factors can cause bad breath (Scully and Greenman, 2012). There have been a number of reports and reviews of halitosis caused by respiratory diseases such as chronic caseous tonsillitis (Rio et al., 2008), tonsilloliths (Ansai et al., 2005; Rio et al., 2008), foreign bodies in the nose (Haumann et al., (2000), adenoid hypertrophy (Sikorska-Żuk and Bochnia (2018), and postnasal drip (Amir et al., 1999). Bronchiectasis and other lung infections such as cancer, asthma and bronchitis, may also cause halitosis (Porter and Scully, 2006; Madhushankari et al., 2015). In this study, the effects of respiratory conditions on halitosis were significant in smokers with oral health problems ($P < 0.01$). All patients with respiratory conditions had halitosis in this study (Node 10), representing a much higher rate than that seen in patients without such respiratory conditions (Node 9; 89.2%).

Metabolic disorders that may result in bad breath include diabetes, hepatic disease, renal disease, trimethylaminuria, dimethylglycinuria, cystinosis, hypermethioninaemia, and liver disease (Scully and Greenman, 2012). In this study, the effects of systemic diseases on halitosis were significant in non-smokers without oral health problems ($P<0.05$). Interestingly, the rate of halitosis was higher in patients without systemic disease (Node 7, 16.5%) than in those with systemic disease (Node 8, 9.1%).

The association between halitosis and gastroesophageal reflux disease remains controversial. Moshkowitz et al. (2007) suggested that halitosis may be a result of gastroesophageal reflux disease. Struch et al. (2008) reported that gastroesophageal reflux disease increases the risk for halitosis in both edentulous and dentate subjects. By contrast, some studies have shown no association between halitosis and erosive gastroesophageal reflux disease (Tas et al., 2011; Kislig et al., 2013). In contrast to previous reports (Moshkowitz et al., 2007; Struch et al., 2008), the effects of gastrointestinal conditions on halitosis were not significant in this study.

We examined the effects of various factors on halitosis and interactions among these factors and have developed a decision tree model to identify the risk factors associated with halitosis that may be useful to develop programs for halitosis diagnosis and management. Oral health problems were more important factors related to halitosis than smoking, respiratory diseases, systemic diseases or sex. Classification tree methods can be used when several factors must be examined together, particularly if the dataset is large.

Author Contributions

MK: data collection or management, manuscript writing and language editing, UNY: data collection or management, AOK: data collection or management, manuscript writing and language editing, AK: data collection or management, FU: statistical analysis, language editing, manuscript editing and corresponding author.

Conflict of Interest

The authors declare that there is no conflict of interest.

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