OBSTRUCTIVE SLEEP APNEA IN ASSOCIATION WITH PERIODONTITIS:
A CASE-CONTROL STUDY

Nuha E. Ahmad

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Approved by:
Dr. Anne Sanders, Ph.D
Dr. Rose Sheats, D.D.S., D.M.D
Ms. Jennifer L. Brame, M.S.DH
Dr. Greg Essick, D.D.S., Ph.D
ABSTRACT

NUHA E. AHMAD: Obstructive Sleep Apnea in Association with Periodontitis: a Case-Control Study
(Under the Direction of Dr. Gregory Essick)

Periodontitis is associated with several cardio-metabolic disorders that are co-morbid with sleep-disordered breathing. A relationship between periodontitis and obstructive sleep apnea (OSA) is plausible, but has received little attention. **Objective:** This study investigated the strength of association between periodontitis and risk for OSA. **Methods:** In this case-control study, cases had moderate or severe periodontitis (n=50; 32.5%) and controls had mild periodontitis, or no periodontitis (n=104; 67.5%). Sixty-one (39.6%) males and 93 (60.4%) females (mean age = 61 years; age range = 19 to 88) were sampled from the dental hygiene preventive care clinic in the School of Dentistry at the University of North Carolina at Chapel Hill between February and April 2011. Patients received a full mouth periodontal examination that included measurement in all teeth present of probing pocket depths and clinical attachment levels at six sites per tooth. The case definition for moderate or severe periodontitis was that of the American Dental Association (ADA). Risk for OSA was determined by the 4-item “STOP” OSA screening questionnaire, which assesses self-reported snoring, excessive daytime sleepiness, witnessed apnea during sleep and history of hypertension. Demographic, general health and orofacial characteristics were recorded that were considered putative predictors of either periodontitis or OSA. A multivariate binary logistic regression assessed odds of moderate or severe periodontitis according to OSA risk with adjustment for potential confounders. **Results:** In all, 59 (38.3 %) patients screened at
high risk for OSA, by providing two or more affirmative responses on the STOP questionnaire. Sixty percent of periodontitis cases (n=30) screened high risk of OSA compared with only 28% (n=29) of controls. Cases were 4.1 times more likely (95% CI: 1.9, 11.4) to be at high risk for OSA than controls (P=0.007) after adjustment for potential confounders including sex, age, smoking, diabetes mellitus and body mass index.

**Conclusion:** A significant association was observed between moderate or severe periodontitis and risk for OSA.
This thesis would be incomplete without a dedication to my cherished husband, Faiz, who sacrificed a lot for me during this journey, which I doubt would have been successful without his unconditional love and support.

To my precious kids, the joy of my life, Malak and Obadah.

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To my sister, brother, uncle, aunts, and parents in-law.

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LIST OF ABBREVIATIONS

OSA  Obstructive sleep apnea
DH   Dental hygiene
ADA  American Dental Association
NHANES National Health and Nutrition Examination Survey
BMI  Body mass index
SES  Socioeconomic status
AHI  Apnea Hypopnea Index
CDC  Centers for Disease Control and Prevention
AAP  American Academy of Periodontology
PPD  Periodontal pocket depth
CAL  Clinical attachment level
REC  Gingival recession
UNC  The University of North Carolina
CVD  Cardiovascular disease
HbA1c Glycosylated hemoglobin A1c
CRP  C-reactive protein
LBW  Low birth weight
ARES Apnea Risk Evaluation System
1. INTRODUCTION

Periodontitis is an infectious disease triggered by microbial plaque accumulation on teeth and gum surfaces, which in turn, induces an inflammatory reaction to protect the host that often leads to tissue destruction. It has been shown to have an association with several systemic health conditions such as cardiovascular disease, diabetes mellitus, low-birth weight, respiratory disease, and rheumatoid arthritis. Periodontitis has many risk factors that affect the presence and severity of the condition such as age, male gender, low socio-economic status (SES), obesity, cigarette smoking, and alcohol consumption.

A recent study conducted by Gunaratnam et al. (2009) demonstrated a relationship between obstructive sleep apnea (OSA) and periodontitis. They found that the prevalence of periodontitis was 77% in patients with confirmed OSA, which was four times the estimate of the Australian national average. Given the reported high prevalence of periodontitis in patients with confirmed OSA, we questioned whether the prevalence of OSA is associated with periodontitis. To address this question, we conducted a study to evaluate the risk for OSA in patients who presented for a dental cleaning with different degrees of periodontitis. The study is described in the second half of this thesis, a manuscript for submission to the *Journal of Dental Hygiene (JDH)*. The first half of this thesis reviews literature relevant to the study.
2. LITERATURE REVIEW

2.1 Periodontitis:

Periodontitis is a common chronic disease that causes inflammation and destruction of the tooth-supporting tissues leading to the development of periodontal pockets, alveolar bone loss, and tooth mobility.\(^{25}\) The infection and host-response begins with colonization and growth of a small group of predominantly Gram-negative, anaerobic bacteria, and spirochetes.\(^{26}\) The bacteria extend apically along the tooth surface to initiate the formation of periodontal pockets, with eventual destruction of the periodontal ligament and alveolar bone.\(^{27}\)

Periodontitis can be modified by behavioral factors, systemic diseases, hormonal imbalance, suppressed immunity, hematological disorders, and can be drug-induced.\(^{28}\)

Periodontitis has different stages, from the mild to the severe form of periodontitis. Mild periodontitis is characterized by generalized (affecting \( \geq 30\% \) of the sites) bleeding on probing and/or suppuration, no alveolar bone loss, 2-3 mm PPD, no CAL, and no mobility and/or furcation involvement. Advanced, severe irreversible periodontitis is characterized by generalized (affecting \( \geq 30\% \) of the sites) severe alveolar bone loss, \( > 7 \) mm PPD, \( \geq 5\) mm CAL, mobility and/or furcation involvement (ADA classification).\(^{29}\)

Gingivitis is the most prevalent form of periodontitis and affects about 75% of adults in the United States, and moderate periodontitis affects about 30%.\(^{30}\) In 2000, a report by the U.S. Surgeon General titled “Oral Health in America” reported that severe periodontitis affects about 14% of adults aged 45 to 54 years old, and 23% of adults aged 65- to 74 years old.\(^{31}\)
Chronic inflammatory periodontitis is one of the most prevalent chronic infections, and a significant risk factor for various systemic diseases.\textsuperscript{31,32} Cardiovascular diseases (CVD) including atherosclerosis, myocardial infarction and stroke, are associated with the presence of periodontitis. Significant associations have been shown between CVDs and periodontitis after adjustment for associated risk factors.\textsuperscript{2,32-34} One of the theories explaining the correlation between these diseases is that periodontal pathogens enter the blood stream by invading the epithelial cells and connective tissues and travel through the human body. These pathogens can invade the endothelium leading to endothelial dysfunction, inflammation and atherosclerosis.\textsuperscript{32} Periodontal pathogen \textit{A. actinomyctemcomitans} has a significant correlation with coronary heart disease.\textsuperscript{35}

Diabetes mellitus is confirmed as a major risk factor for the presence and severity of periodontitis.\textsuperscript{36,37} Diabetes mellitus has a bidirectional relationship with periodontitis.\textsuperscript{38,39} One view of the relationship is that periodontitis can lead to type-2 diabetes by negatively affecting glycemic control. Taylor (1996) showed that diabetic patients with periodontitis have a greater risk of worsening glycemic control compared to diabetic patients without periodontitis.\textsuperscript{40} Evidence suggests additionally that periodontitis lead to a significant increase in glycated haemoglobin (HbA1c) and high sensitivity C-reactive protein (CRP), which may be associated with poor glycemic control.\textsuperscript{41} Multiple studies have shown a significant effect in the reduction in HbA1c levels following periodontal therapy.\textsuperscript{42,43} Alternatively, periodontitis can develop from the biological sequel of type 1 or type 2 diabetes mellitus.\textsuperscript{7} For example, Shlossman (1990) showed that diabetes increases the risk of alveolar bone loss and attachment loss approximately threefold when compared to non-diabetic individuals.\textsuperscript{44}
Respiratory diseases such as aspiration pneumonia and lower respiratory tract infections can be induced or exacerbated by the aspiration of oral bacterial biofilms. The oral bacteria found on the respiratory mucosa releases enzymes that promote the colonization of respiratory pathogens.

Many studies have shown a positive association between preterm birth and low-birth weight (LBW) in the presence of periodontitis. Periodontal pathogens cause systemic inflammation and infections. The mother’s immune system responds to infection by releasing inflammatory mediators that may result in preterm delivery and LBW.

The prevalence and severity of periodontitis are affected by several sociodemographic factors such as male gender, older age, higher BMI (obesity), low educational attainment level, and low SES. It is also affected by behavior such as cigarette smoking and alcohol consumption.

2.2 Obstructive Sleep Apnea and Periodontitis:

Of most relevance to the present study is a report suggesting that OSA is a risk factor for periodontitis. In this cross-sectional study, Gunaratnam et al (2009), assessed the periodontal disease status of 66 adults in Australia, all of whom were newly diagnosed with OSA (AHI >5 respiratory events per hour) at a sleep disorders clinic in a university teaching hospital before receiving any treatment. A standard periodontal examination determined the presence and severity of periodontitis and included measurements of periodontal pocket depth (PPD), clinical attachment level (CAL), gingival recession (REC), bleeding upon probing, gingival index, and plaque index. The investigators defined periodontitis using two definitions. The Centers for Disease Control and Prevention (CDC) and the American
Academy of Periodontology (AAP) define periodontitis as the presence of two or more interproximal sites with $\geq 4$ mm CAL, not on the same tooth, or two or more interproximal sites with PPD $\geq 5$ mm, not on the same tooth. Alternatively, the National Center for Health Statistics (NCHS) defines periodontitis as the presence of at least one site with PPD $\geq 4$ mm and CAL $\geq 3$ mm at the same site on the same tooth. Gunaratnam et al. (2009) found that the prevalence of periodontitis in the study group was 77% using the (CDC/APA) definition, and 79% using the (NCHS) definition. Under both definitions, prevalence was approximately four times higher than estimates for the Australian adult population in 2004-2006. The authors suggested that because both OSA and periodontitis share an underlying inflammatory basis, a common biological pathway for the association was plausible. They also suggested that periodontitis could be an unknown confounder in the association between OSA and CVD. However, the study’s findings were limited by a lack of data from a comparison group without OSA.²⁴

### 2.3 Obstructive Sleep Apnea (OSA)

Obstructive sleep apnea is defined as a condition of disturbed sleep characterized by repetitive full or partial collapse of the upper airway lasting for at least 10 seconds,⁵⁸-⁶⁰ resulting in periods of repetitive airflow cessation (apnea) or reduction (hypopnea).⁶¹ The upper airway blockage is usually caused by the relaxation of the muscles at the base of the throat (pharyngeal and tongue muscles),⁵⁸,⁶² causing insufficient airflow into the lungs, leading to upper airway collapsibility that results in periods of asphyxia that lead to hypoxia.⁶³-⁶⁵ As the body responds with increased effort to breathe normally again, it stimulates the sympathetic nervous system and causes arousals from sleep.⁶⁶,⁶⁷ Clinically, the condition
frequently presents as habitual loud snoring, apnea (periods of paused breathing) witnessed by a bed partner, arousal during sleep, and sleepiness and fatigue during the day.\textsuperscript{68, 69}

OSA is typically diagnosed in a sleep laboratory, during an overnight sleep study using polysomnography. The severity of the disorder is determined according to the frequency of airway collapse and is expressed as the apnea-hypopnea index (AHI).\textsuperscript{66, 70} An AHI that is \(<5\) events per hour is considered normal, an AHI of \(5-15\) events per hour is mild and an AHI of \(>15-30\) per hour is moderate, and AHI \(>30\) is a severe form.\textsuperscript{68} Multiple validated screening questionnaires have been developed to assess an individual's risk for OSA in various, often pre-surgical, settings. These include the Berlin questionnaire, the apnea risk evaluation system (ARES), the STOP, and the STOP-Bang questionnaires.\textsuperscript{58, 71-74} Individuals who screen at high risk should be referred to their physician for evaluation.

OSA is a life-threatening, underdiagnosed condition. It is also considered to be one of the most common forms of disordered sleep, affecting approximately 18 million men, women, and children in the United States.\textsuperscript{75} OSA substantially affects 24\% adult males and 4\% adult females in the general population.\textsuperscript{59} It has been estimated that one in six adults has at least mild obstructive sleep apnea, and one fourth of those have severe obstructive sleep apnea.\textsuperscript{76} It has also been estimated that up to 93\% of women and 82\% of men with moderate to severe obstructive sleep apnea remain undiagnosed.\textsuperscript{72}

As a life-threatening condition, OSA is associated with various systemic comorbidities such as hypertension,\textsuperscript{62, 77} congestive heart failure,\textsuperscript{60} coronary artery disease,\textsuperscript{60} myocardial infarction,\textsuperscript{78} cardiac arrhythmia,\textsuperscript{79} stroke,\textsuperscript{80} impaired glucose tolerance, and type II diabetes mellitus.\textsuperscript{82, 83} It also has an impact on depression, social functioning, work performance, and increased accident rates due to daytime sleepiness.\textsuperscript{84}
OSA shares some of the risk factors of periodontitis including male gender, age, obesity, oral breathing, cigarette smoking, and alcohol consumption. It was also suggested that periodontitis might be a risk factor for OSA.

2.4 Risk Assessment for OSA

Several OSA screening tools can be used in a dental setting. A retrospective analysis to assess the prevalence of risk to OSA in two dental setting used the ARES screening questionnaire. Responses were obtained from 175 men and 156 women. It was found that 25% of the men and 60% of the women had no apparent risk of having OSA, while 34% and 6% respectively, were predicted to have moderate or severe OSA. Of these patients, 105 (not previously diagnosed with OSA) completed an in-home sleep study, 96% were confirmed to have at least mild OSA (AHI>5), and 84% had greater than 10 events per hour and 70% had at least 15 events per hour.

The STOP questionnaire was developed for use on patients before surgery. It consists of 4 questions: Snoring, Tiredness during day, Observed apnea, and high blood Pressure. It has been validated on preoperative patients and the scores were evaluated in relation to the AHI. The sensitivities/specificities of the STOP questionnaire with the AHI cutoffs of greater than 5 events/hour was 65.5%/60%, greater than 15 events/hour was 74.3%/53.3%, and greater than 30 events/hour was 79.5%/48.6%. However, upon adding 4 more questions regarding the Body Mass Index, Age, Neck circumference, and Gender (STOP-BANG) the sensitivities/specificities changed to 83.6%/56.4%, 92.9%/43%, and 100%/37% respectively with the same AHI cutoffs. Abrishami et al. (2010) recommended using the STOP or STOP-BANG questionnaires for their high-quality methodological and reasonably
accurate results, after comparing the STOP, STOP-BANG, Berlin, Apnea Score, and Wisconsin questionnaires.\textsuperscript{72}

In the study described below, the STOP questionnaire was utilized rather than the ARES questionnaire because it is easier to use and the ARES questionnaire is proprietary. Furthermore, the STOP questionnaire has greater specificity than the STOP-BANG questionnaire; therefore, it was considered a better choice for the purpose of the study.

\textbf{2.5 Factors Associated with Periodontitis}

Many factors associated with periodontitis are likewise associated with OSA. Consequently statistical adjustment of these factors is necessary to control for their potential confounding when examining the relationship between OSA and periodontitis.

\textbf{A. Gender:}

\textit{i) Gender and Periodontitis:}

Several studies have reported that the prevalence of periodontitis is greater in males than females.\textsuperscript{11,13} For example, Albandar et al. (1999) reported in individuals 30-54 years of age, a prevalence of periodontitis of 34\% in males and 23\% in females.\textsuperscript{11} In individuals 55-90 years of age, the prevalence was 56\% in males and 44\% in females.\textsuperscript{11}

\textit{ii) Gender and OSA:}

The literature is replete with reports of a higher prevalence of OSA in males than in females.\textsuperscript{59,85,88} Young et al. (1993) reported that the male to female ratio was as high as 10:1.\textsuperscript{59}
**B. Age**

*i) Age and Periodontitis:*

Age is an important risk factor for periodontitis; many studies have reported that the prevalence and extent of periodontitis increase considerably with age.\(^6,11\) Albanadar et al. (1999) reported that 29% of persons aged 30 to 54 years old had periodontitis, compared with 50% aged 55 to 90 years.\(^11\)

*ii) Age and OSA:*

Many studies report that increasing age is as a risk factor for OSA.\(^59,86,87,95,96\) Moreover, prevalence of OSA increases 2 to 3 times in adults aged \(\geq 65\) years compared with middle-aged adults aged 30-46 years.\(^96\)

**C. BMI**

*i) BMI and Periodontitis:*

The literature reports a positive association between BMI and periodontitis.\(^16-20\) Chaffee (2010) conducted a meta-analysis of 57 independent studies examining evidence of the relationship between BMI and periodontitis and concluded that an increase in BMI is associated with increased odds of periodontitis.\(^19\) The mechanism underlying the association is poorly understood, but it is understood that obesity, specifically central obesity, has several harmful biological effects that may play a role in the pathogenesis of periodontitis. Elsewhere, Saito (2001) suggested that visceral fat accumulation is associated with a risk of periodontitis as well as CVD.\(^20\)
ii) BMI and OSA:

BMI is considered a prominent risk factor for OSA. It is estimated that about 70% of those with OSA are obese. Moreover, 26% of patients with a BMI>30 and 33% of those with a BMI > 40 have moderate OSA. Although the underlying association is not clear, increased weight can cause the pharyngeal airway size to diminish.

D. Cigarette smoking status

i) Cigarette smoking and Periodontitis:

Various epidemiological studies report cigarette smoking is a significant risk factor for periodontitis. In fact, Bergström (1989) found that smokers have 2.5 to 3.5 times greater risk of severe periodontal attachment loss than never smokers.

ii) Cigarette smoking and OSA:

In addition, many epidemiological studies have reported smoking as a risk factor for OSA. Upper airway edema is thought to be the underlying mechanism for this relationship.

E) Alcohol/Sedative use Before Bedtime

i) Alcohol/sedative use before bedtime and Periodontitis:

Several studies have suggested that alcohol consumption in general, with no restriction to bedtime, is a risk factor for oral diseases, including periodontitis, as it increases host susceptibility to infection.
ii) Alcohol/sedative use before bedtime and OSA:

Previous studies have shown that alcohol consumption is a risk factor for OSA. Alcohol relaxes the upper airway muscles and increases airway resistance, thereby increasing the potential of apneas and hypopneas.\textsuperscript{70, 92}

\textbf{F) Diabetes}

i) Diabetes and Periodontitis:

Many studies that indicated that diabetes and poor glycemic control are significant risk factors for periodontitis and the relationship is bidirectional.\textsuperscript{7, 38, 40, 100}

ii) Diabetes and OSA:

Multiple studies have showed that OSA is associated with Type II diabetes and insulin intolerance.\textsuperscript{82, 101, 102} The Wisconsin Sleep Cohort cross-sectional study found that self-reported diabetes was three to four times more prevalent in patients with an AHI \( \geq 15 \) events/hour or greater than in those with an AHI < 5 events/hour.\textsuperscript{76}

\textbf{G. Nasal Breathing Difficulty (mouth breathing)}

i) Nasal breathing difficulty (mouth breathing) and Periodontitis:

To our knowledge, no studies have been conducted with adults. However, a relationship between mouth breathing and periodontitis has been reported in teenagers.\textsuperscript{103}

ii) Nasal breathing difficulty (mouth-breathing) and OSA:

Several studies have reported an association between nasal obstruction and OSA.\textsuperscript{104, 105} Lofaso et al. (2000) reported that patients with OSA syndrome tended to have higher nasal resistance than snorers without OSA syndrome, and that nasal resistance is an independent
risk factor for OSA syndrome. Koutsourelakis et al. (2006) reported that oral or oro-nasal breathing increases with increasing severity of OSA even in patients free of nasal obstruction.  

**H. Dry Mouth**

i) Dry mouth and Periodontitis:

There is little evidence that dry mouth has a direct influence on periodontitis, and this may be because saliva does not enter into the periodontal pockets where the bacterial pathogens are located.

ii) Dry mouth and OSA:

Dry mouth has been reported as a significant outcome or symptom of OSA, especially upon waking, primarily due to sleeping with an open mouth and mouth breathing.

**I. Educational attainment**

i) Educational attainment and Periodontitis:

A meta-analysis conducted by Boillot (2011) concluded that low educational attainment is associated with increased risk for periodontitis.

ii) Educational attainment and OSA:

No studies pertaining to this subject were found.

**J. Socioeconomic Status**

i) Socio-economic status and Periodontitis:
A significant inverse association between SES and periodontitis has been reported in several studies. Specifically, patients with high SES have healthier periodontium than patients with low SES.\textsuperscript{14, 15}

ii) Socio-economic status and OSA:

Several studies have demonstrated a relationship between SES and OSA in children,\textsuperscript{22} however, to our knowledge, no studies have demonstrated a relationship between SES and OSA in adults.
3. MANUSCRIPT INTRODUCTION AND LITERATURE REVIEW

Periodontitis results from an interaction between bacterial infection and host immunological and inflammatory responses. The disease is characterized by destruction of the tooth-supporting tissues leading to the development of periodontal pockets, alveolar bone loss, and tooth mobility. Epidemiologic data from NHANES 1999-2004, estimate the prevalence of moderate or severe periodontitis among dentate adults aged 20-64 years to be 9.3% and among older adults to be 26.6%.

Periodontitis is a suspected risk factor for low-birth weight and for many systemic diseases, such as cardiovascular disease, stroke, diabetes mellitus, respiratory disease, and rheumatoid arthritis. The inflammation surrounding the teeth occurs as the immune system responds to the accumulation of bacterial plaque on the teeth and gums, and is modified by behavioral factors, systemic disease, medications, and immune and hematological disorders. Furthermore, the presence of systemic disorders can also affect the efficacy of periodontal therapy.

The prevalence and severity of periodontitis increase with age, are greater among male than female adults and greater in adults with low socio-economic status (SES) relative to their higher SES counterparts. Obesity, nasal breathing difficulty, cigarette smoking, and alcohol consumption are positively associated with periodontitis.
Of most relevance to the present study are findings from a small exploratory study (n=66) conducted in Australia by Gunaratnam, et.al (2009). The investigators reported a significant positive relationship between polysomnography derived apnea hypopnea index (AHI) > 5 events/hour and periodontitis. In that study, the case definition of moderate or severe periodontitis was that of the Centers for Disease Control and Prevention and the American Academy of Periodontology (CDC/AAP). That defines moderate or severe periodontitis as the presence of two or more interproximal sites with ≥4 mm CAL, not on the same tooth, or two or more interproximal sites with PPD ≥5 mm, not on the same tooth. The investigators found that the prevalence of periodontitis was 77% in the study group, which was four times the national average for a representative sample of the adult Australian population using the same CDC/AAP periodontitis case classification. The authors suggested that because both OSA and periodontitis share an underlying inflammatory basis, a common biological pathway for the association was plausible. However, the study’s findings were limited by a lack of data from a comparison group without OSA.

OSA is the most common form of sleep-disordered breathing, estimated to affect 18 million individuals in the United States. Data from the Wisconsin Cohort Study indicate that the prevalence of OSA in people between the ages of 30 and 60 years was 9% to 24% for men and 4% to 9% for women. Characterized by repetitive full or partial collapse of the upper airway, OSA results in periods of asphyxia, hypoxia, arousal from sleep, stimulation of the sympathetic nervous system, and altered immunity. Clinically, the condition frequently presents as habitual loud snoring, apnea witnessed by a bed partner, arousal during sleep, and sleepiness and fatigue during the day. As a life-threatening condition, OSA is associated with hypertension, congestive heart failure, coronary artery disease, and
myocardial infarction, cardiac arrhythmia, stroke, impaired glucose tolerance, and type II diabetes mellitus.

Shared risk factors for periodontitis and OSA include male sex, older age, obesity, oral breathing, cigarette smoking, and alcohol consumption. OSA is formally diagnosed during an overnight sleep study using polysomnography to grade the severity of the disorder according to the frequency of airway collapse, expressed as the apnea-hypopnea index (AHI). However, screening tools exist that assess an individual’s risk for OSA in various, often presurgical, settings.

Given the reported high prevalence of periodontitis in patients with confirmed OSA, we questioned whether the prevalence of OSA was associated with the severity of periodontitis. To address this question, we evaluated the risk for OSA in patients with different degrees of periodontitis severity as determined during the patients’ scheduled dental visit. The risk for OSA was assessed using the STOP questionnaire, a validated screening questionnaire. Data were obtained also for potentially confounding factors, such as age and gender, which are associated with increased risk for periodontitis and/or OSA.
4. METHODS AND MATERIALS

4.1 Study Design:

In this case control study, cases had moderate or severe periodontitis (case types III and IV). Dentate patients having gingivitis or slight (early) periodontitis (case types I and II) were classified as controls (see appendix for detailed case classification).

4.2 Study Population and Recruitment Procedures:

Study participants were patients treated between February and April 2011 in the dental hygiene preventive care clinic at the University of North Carolina (UNC) School of Dentistry. Inclusion criteria were being dentate and aged 18 years or older. Edentulous patients and patients with healthy periodontium were excluded from participation. Potential patients were approached by the first author (hereafter referred to as the investigator) after the patients’ scheduled dental cleaning was completed by the assigned dental hygiene student. Each patient was given a brief description of the study along with educational materials on OSA, after which verbal consent was obtained. The protocol was approved by the Institutional Review Board at the UNC–Chapel Hill.

4.3 Data collection:

Following consent, each patient completed a sociodemographic/behavioral questionnaire while the investigator completed a clinical characteristics questionnaire. Both questionnaires were processed using Cardiff TeleForm® (version 10.5.1© 2010 Verity, Inc.),
an optical scanning system that efficiently transfers penciled information to an electronic format for statistical analysis. The questionnaires were designed to obtain data for this study as well as for a separate analysis of sociodemographic and clinical characteristics associated with high risk of OSA, an analysis that is not included in this publication. No identifying data were included on either questionnaire.

4.4 Sociodemographic/Behavioral Questionnaire:

This questionnaire was used to obtain information about the patient’s age, gender, weight, height, education and annual household income; sleep quality (snoring, observed apnea, tiredness during the day, Epworth Sleepiness Scale, teeth grinding, and nasal-breathing difficulty); social habits (smoking, alcohol, and sedative consumption before bedtime); and medical history (high blood pressure, diabetes mellitus, previous diagnosis with OSA or any form of sleep-disordered breathing, and any previous or current treatment for OSA).

4.5 Clinical Characteristics Questionnaire:

The investigator completed this questionnaire recording relevant clinical observations, some of which were directly observed by the investigator. Other items were observations made by the dental hygiene student, confirmed by the clinical instructor, and recorded in the patient’s dental chart, from which the investigator extracted pertinent information. On the questionnaire, physical measurements were recorded of the patient’s blood pressure (taken by the assigned dental hygiene student), body-mass index (BMI; calculated by the investigator using the patient’s self-reported weight and height), and neck
circumference (measured by the investigator using a disposable tape measure). Observations of the oral soft tissue included the presence of dry mouth (as assessed by the moistness of the oral mucosa, and whether the mouth mirror easily stuck to the buccal mucosa \(^{112}\) as reported by the dental hygiene student), the presence of macroglossia or large tongue (as assessed by the investigator examining the lateral and anterior borders of the tongue, \(^{113}\) and the Mallampati score \(^{114,115}\) and tonsils grade \(^{114,116}\) both of which were assessed by the investigator while the patient was in a seated position, with the head in full extension, the tongue out, and with phonation. \(^{117}\) Observations of oral hard tissue included the attrition of teeth (as measured by the investigator using the Basic Erosive Wear Examination \(^{118}\) using the highest score per sextant), overjet (as measured by the dental hygiene student using a calibrated dental probe), and the morphology of the maxillary arch (as assessed by the investigator observing the shape of the hard palate).

The remaining items (approximately half) on the clinical characteristics questionnaire pertained to the patient’s periodontal status. Recorded periodontal indices included the Plaque Index \(^{119}\), Gingival Index \(^{119}\), and Bleeding Index \(^{119}\) (all of which were measured by the dental hygiene student). Periodontal measurements, also assessed by the dental hygiene student using a calibrated probe, included the periodontal pocket depth (PPD; the distance from the gingival margin to the base of the pocket) and gingival recession (REC; the distance from the cemento-enamel junction to the gingival margin). The patient’s periodontal case classification—based on a detailed clinical periodontal charting with radiographic interpretation of the bone levels as prescribed by the American Dental Association, 1986 \(^{29}\) was obtained directly from the patients’ chart. Based primarily on the severity of attachment loss, the patient was classified into one of four categories: case type I: gingivitis, case type II:
slight (early) periodontitis, case type III: moderate periodontitis, or case type IV: advanced (severe) periodontitis (see appendix for more information).

4.6 Data Analysis and Statistical Methods:

Using relevant patient-reported responses to the Symptom/Health Questionnaire, the patient’s risk of OSA was calculated as described for the validated OSA screening instrument known as STOP questionnaire. The four questions assess (i) the presence of loud snoring (S), (ii) frequent daytime sleepiness and tiredness (T), (iii) observed (O) apnea during sleeping, and (iv) high blood pressure (P). Responses to each question are “Yes” or “No”. According to the questionnaire’s scoring algorithm, affirmative responses to any two or more of these four questions denotes high risk for OSA. Affirmative responses to fewer than two questions denotes low risk for OSA.

Descriptive statistics summed the number of patients responding affirmatively to none, one, two, three, or four of the STOP OSA screening items. The number and proportion of patients at high risk for OSA were calculated. Exploratory analyses were performed to describe the distribution of affirmative responses to each of the four STOP OSA screening items. The association between the study population’s sociodemographic, behavioural, and clinical characteristics and risk for OSA was tested for statistical significance using Fisher’s exact test for dichotomized risk indicators and Pearson’s chi-square test for categorical risk indicators. Potential covariates were limited to characteristics that have been associated with risk of periodontitis and/or OSA: gender, age, BMI, educational attainment, annual household income, cigarette smoking.
alcohol/sedative consumption before bed, \textit{impaired nasal breathing,} \textit{and dry mouth.} Covariates were included in multivariable binary logistic regression models if their associations in unadjusted analyses with either outcome, OSA risk or periodontitis, were significant at the $p < 0.2$ level. Multivariable binary logistic regression was used to estimate the odds ratio and 95% confidence interval associating moderate/severe periodontitis with high risk for OSA with adjustment for confounding. Analyses were conducted using STATA/IC software version 12.0 (StataCorp. 2011).
5. RESULTS

The study population of 154 patients comprised 50 cases (32.5%) and 104 controls (67.5%). Based on the STOP questionnaire, 38.3% of the all study patients were at high risk for OSA, providing affirmative responses to two items (27.7%), three items (9.7%), or all four items (1.2%, see Figure 1). The likelihood of being classified a case increased with the number of affirmative responses ($p=0.002$, see Table 1), suggesting a crude association between OSA and periodontitis.

A higher percentage of cases than controls were at high risk for OSA for each STOP questionnaire item (Table 2). Moreover, cases and controls differed significantly on the report of high blood pressure (P item, $p=0.006$) and tiredness/sleepiness during the day (T item, $p=0.016$). The proportion of cases was almost twice that of controls for these two STOP questionnaire items.

**Univariate analyses:** Univariate analyses were undertaken to determine if each of eight characteristics was associated with the risk of OSA (Table 3). A significant positive association was observed with age ($p=0.018$), self-reported diabetes mellitus ($p=0.008$), and dry mouth ($p=0.002$, Table 3).

Univariate analyses were undertaken to determine if each of 10 characteristics was associated with moderate or severe periodontitis (Table 4). Odds ratios of moderate or severe periodontitis increased with age; patients who were 70 years old and older had 5.9 times greater odds (95% CI: 2.0 – 16.9) of moderate or severe periodontitis than patients aged less
than 50 years. Current cigarette smokers had 2.4 times greater odds (95% CI: 0.6 – 8.9) of moderate to severe periodontitis than patients who had never smoked. Patients who reported being diabetic had 3.8 times greater odds (95% CI: 1.4 – 10.0) of having moderate to severe periodontitis than patients who reported not being diabetic.

**Multivariable Analyses:** A multivariate binary logistic regression was performed with case status (‘1’ = case, moderate or severe periodontitis; ‘0’ = control, gingivitis or slight periodontitis) as the dependent variable. Independent variables were those patient characteristics that met criteria based on the univariate analyses (Table 5). It was found that patients at high risk of OSA had 4.1 times greater odds (95% CI: 1.5, 11.4) of moderate or severe periodontitis than patients at low risk, after adjustment for potential confounders. Significant covariates included age (95% CI: 1.2, 2.6), smoking (95% CI: 3.2, 191.2), and nasal-breathing difficulty (95% CI: 0.01, 0.9). Diabetic patients had 2.7 times greater odds for having moderate or severe periodontitis, but the 95% confidence interval was equivocal (0.6, 11.4).
6. DISCUSSION

The results of this study extend the finding of Gunaratnam et al. (2009) that prevalence of periodontitis may be higher in patients with OSA. Specifically, the present study suggests that odds of moderate or severe periodontitis were elevated 4.1-fold (95% CI: 1.5, 11.4) among patients screening high risk relative to low risk for OSA after adjustment for potential confounders. The two studies, however, differ in a number of ways. Gunaratnam et al. (2009) studied patients who were clinically diagnosed with OSA. In contrast, we compared periodontitis cases and controls and estimated their risks of OSA using a validated questionnaire. Unlike Gunaratnam et al. (2009) it remained unknown whether the patients in the present study, in general, had OSA. In both studies, periodontitis was diagnosed and classified by clinical examination. While findings of both studies suggest that the prevalence of periodontitis is greater in patients with OSA, the case control study design used in the present study provided a higher level of evidence in support of this association.

6.1 Mechanisms underlying association between periodontitis and OSA:

Gunaratnam et al. (2009) suggested that the increased prevalence of periodontitis in OSA patients could be due to a true association between OSA and periodontitis: Obstructive sleep apnea could act as an inflammatory mediator for periodontitis or vice versa. It is also possible that an increased prevalence of mouth breathing in patients with OSA could exacerbate periodontitis and underlie the association. However, in the present study, there
was no association between the presence of dry mouth and periodontitis. Moreover, patient who reported more difficulty with nasal breathing (presumably favoring oral to nasal breathing) were less likely to exhibit moderate or severe periodontitis. Given that periodontitis and OSA are co-morbid with a large number of pathological conditions, it is also possible that their association is not causative but rather a reflection of their relationship to these common co-morbid conditions.  

6.2 Confounding variables:

The multivariable analysis took into account a number of factors that have been associated with periodontitis, some of which have also been associated with sleep-disordered breathing. These are briefly discussed in the sections below in the order observed in Table 5.

a. Gender: Although the present study did not demonstrate a significant association between gender and the severity of periodontitis, several studies have reported that the prevalence of periodontitis is greater in males than in females.  

b. Age: Age is an important risk factor for periodontitis in many studies. Both the prevalence and extent of periodontitis increase with age. For example, Albandar et al. (1999) showed that 29% of persons in the aged 30 to 54 years old had periodontitis, compared with, 50% aged 55 to 90 years old. The present study confirmed a positive association between age and periodontitis and found that patients who were 70 years and
older had 1.76 times greater odds (95% CI: 1.17 – 2.64) of moderate or severe periodontitis than patients who were between 18-49 years old.

c. **BMI:** The present study did not find a significant association between BMI and the severity of periodontitis. This stands in contrast to reported findings by other investigators.\(^{16-19}\) Chaffee (2010) conducted a systematic review and meta analysis of 57 independent studies on the association between BMI and periodontitis, and identified a slight linear increase in the odds of periodontitis with increasing BMI.\(^{19}\)

d. **Cigarette smoking status:** This study demonstrated a significant association between current cigarette smoking and the severity of periodontitis, where current smokers had 24.9 times greater odds (95% CI: 3.2 – 191.2) of having moderate or severe periodontitis than never smokers, the lack of precision was attributed to the small sample size. A similar finding has been observed by many previous epidemiological studies reporting smoking as a significant risk factor for periodontitis.\(^{21,52-54}\) For example, Bergström (1989) found that smokers have 2.5 to 3.5 times greater risk of severe periodontal attachment loss than never smokers.\(^{52}\)

e. **Alcohol/Sedative use Before Bedtime:** Although the current study did not find a significant association between alcohol consumption before bedtime and severity of periodontitis, several studies have suggested that alcohol consumption in general, with no restriction to bedtime, is a risk factor for oral diseases, including periodontitis, as it increases the host’s susceptibility to infection.\(^{55,56}\) Our finding may have not demonstrated an association due to limiting the question to a specific time of day.

f. **Diabetes:** The present study found that patients who reported being diabetic had 2.70 times greater odds (95% CI: 0.64 – 11.37) of having moderate to severe periodontitis
than patients who did not report being diabetic. This finding has been supported by many studies that indicate that diabetes and poor glycemic control are significant risk factors for periodontitis and vice versa.  

\[7, 38, 40, 100\]

**g. Nasal Breathing Difficulty (mouth breathing):** The results of this study indicate that difficulty with nasal breathing favored slight periodontitis or gingivitis rather than moderate or severe periodontitis: Patients with nasal breathing difficulty had 0.09 (95% CI: 0.01 – 0.88) times the odd of having moderate or severe periodontitis of patients with no nasal breathing difficulty. To our knowledge, no studies have addressed the relationship between mouth breathing and periodontitis in adults; however, a relationship has been reported in teenagers.  

\[103\]

**h. Dry Mouth:** The results of this study did not demonstrate a significant relationship between dry mouth and the severity of periodontitis. Moreover, there is little published evidence to suggest that dry mouth has a direct influence on periodontitis. This may be because saliva does not enter into the periodontal pockets where the bacterial pathogens are located.  

\[106\]

**i. Educational attainment:** Although this study did not demonstrate a significant association between educational attainment and the severity of periodontitis, a meta-analysis conducted by Boillot (2011) concluded that low educational attainment is associated with increased risk for periodontitis.  

\[51\]
j. Socioeconomic Status: The results of this study did not demonstrate an association between SES and the severity of periodontitis; however, a significant association has been reported in several studies. Specifically, patients with high SES have been reported to have healthier periodontium than patients with low SES.\textsuperscript{14,15}

An important strength of this study is that periodontitis cases and controls were drawn from the same source population during the same time interval. All patients underwent the same measurements of periodontal health and OSA screening which were performed by the same clinicians. This enhances the principal of comparability, by ensuring less variability and a reduced risk of confounding.

6.3 Limitations of Study:

This study relied on periodontal data collected by multiple examiners. However, all examiners were calibrated on the periodontal assessment and classification, and the supervising faculty confirmed the assessments before they were entered into the patients’ records. Each classification was defined by precise measurements of periodontal pocket depth (PPD), clinical attachment level (CAL), mobility, and/or furcation involvement and by whether these conditions were localized (< 30% of the site) or generalized (≥ 30% of the site). This reduced the risk of case status misclassification.

The major limitation of this study is the uncertainty in the proportions of the cases and controls with and without obstructive sleep apnea, respectively. The STOP questionnaire is a measure of risk for sleep apnea but falls short of clinical diagnosis. This questionnaire was developed for the pre-surgical assessment of patients prior to general anesthesia and administration of agents that depress respiration. Its diagnostic usefulness has been
determined for patients with different severity levels of OSA based on the AHI. Specifically, it’s sensitivity and specificity with the AHI cutoff >5 events/hour are estimated to be 65.5% and 60%, respectively; >15 events/hour, 74.3% and 53.3%; and >30 events/hour, 79.5% and 48.6%. Though some other screening questionnaires have been shown to have higher diagnostic sensitivity, such as the STOP-BANG questionnaire, the STOP questionnaire was chosen for this study because of its higher specificity. However if misclassification of OSA status is non-differential, i.e. unrelated to periodontitis status, which we believe to be the case, then the effect of any misclassification bias is towards the null. What this means is that the odds ratio for the strength of the relationship between OSA risk and periodontitis shifts toward 1.0, making our estimate more conservative than it would otherwise be.

6.4 Relevance to Dental Hygienists:

Patients visit the dental office more frequently than the physician’s office; moreover, dental cleaning is the most common periodically performed procedure in dentistry. One of the dental hygienists’ responsibilities is to assess patients’ overall well-being as well as to facilitate health promotion, disease prevention, and patient education. The STOP screening questionnaire is an easy, time efficient questionnaire that if included with the health history and periodic recall assessments, could help identify patients at high risk for a serious life-threatening condition. Moreover, the dental hygienist is optimally positioned in the dental practice to make soft tissue observations that have been associated with increased risk for OSA. By screening patients for sleep-disordered breathing, the dental hygienist supports the practice in fulfilling a greater role in the public health of the community.75, 122, 123
7. CONCLUSION

This case-control study found a positive significant association between moderate or severe periodontitis and high risk for OSA, based on the STOP questionnaire, after adjustment for potential confounders. Further investigation of this association using objective measures of obstructive sleep apnea (polysomnography or home sleep test) is warranted. The STOP questionnaire is a simple, inexpensive screening tool could be included with the health history forms and used to identify dental patients at high risk for a life-threatening medical condition. Further investigation should include sleep study to confirm the presence or absence of OSA in patients with and without OSA. As well as to further investigate the underlying pathophysiological mechanisms of both conditions that can better explain the significant association.
TABLES AND FIGURES

Figure 1. Histogram showing distribution of study participants according to their number of affirmative responses on the 4-item STOP obstructive sleep apnea (OSA) screening questionnaire. The dashed vertical line at two (2) represents the thresholds above which participants are considered at high risk for obstructive sleep apnea. Of the 154 participants in this study, 38.3% (n=59) screened at high risk for obstructive sleep apnea.
Table 1: Percent of periodontitis cases according to number of affirmative responses on the STOP obstructive sleep apnea screening questionnaire.

<table>
<thead>
<tr>
<th>Number of affirmative responses to STOP items</th>
<th>Gingivitis or slight periodontitis (%)</th>
<th>Moderate or severe periodontitis (%)</th>
<th>P-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>77.1</td>
<td>22.9</td>
<td>0.002</td>
</tr>
<tr>
<td>1</td>
<td>80.0</td>
<td>20.0</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>52.4</td>
<td>47.6</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>46.7</td>
<td>53.3</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>0.0</td>
<td>100.0</td>
<td></td>
</tr>
</tbody>
</table>
Table 2: Response to individual items on the STOP obstructive sleep apnea (OSA) screening questionnaire\(^{(a)}\) and relationship with periodontitis case status.

<table>
<thead>
<tr>
<th>STOP screening questionnaire items</th>
<th>Response</th>
<th>N (%)</th>
<th>Moderate or severe periodontitis (%)</th>
<th>P-value (^{(b)})</th>
</tr>
</thead>
<tbody>
<tr>
<td>S Do you snore loudly?</td>
<td>No</td>
<td>124 (80.5)</td>
<td>29.8</td>
<td>0.157</td>
</tr>
<tr>
<td></td>
<td>Yes</td>
<td>30 (19.5)</td>
<td>43.3</td>
<td></td>
</tr>
<tr>
<td>T Do you often feel tired, fatigued, or sleepy during the day?</td>
<td>No</td>
<td>83 (53.9)</td>
<td>24.1</td>
<td>0.016</td>
</tr>
<tr>
<td></td>
<td>Yes</td>
<td>71 (46.1)</td>
<td>42.3</td>
<td></td>
</tr>
<tr>
<td>O Has anyone observed you stop breathing during your sleep?</td>
<td>No</td>
<td>132 (85.7)</td>
<td>31.1</td>
<td>0.361</td>
</tr>
<tr>
<td></td>
<td>Yes</td>
<td>22 (14.3)</td>
<td>40.9</td>
<td></td>
</tr>
<tr>
<td>P Do you have or are you being treated for high blood pressure?</td>
<td>No</td>
<td>80 (51.9)</td>
<td>22.5</td>
<td>0.006</td>
</tr>
<tr>
<td></td>
<td>Yes</td>
<td>74 (48.1)</td>
<td>43.2</td>
<td></td>
</tr>
</tbody>
</table>

\(^{(a)}\) The STOP questionnaire classifies persons as high risk for OSA with affirmative responses to \(\geq 2\) STOP questions; low risk is defined as \(<2\) affirmative responses

\(^{(b)}\) P-value tests the null hypothesis that no difference exists between response to the OSA screening question and periodontitis case status
Table 3: Relationship of study participant characteristics and high risk for obstructive sleep apnea

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>N (%)</th>
<th>Percent with High Risk</th>
<th>P-value</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Total</strong></td>
<td>154 (100.0)</td>
<td>38.3</td>
<td></td>
</tr>
<tr>
<td><strong>Gender</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Female</td>
<td>93 (60.4)</td>
<td>37.6</td>
<td>0.831</td>
</tr>
<tr>
<td>Male</td>
<td>61 (39.6)</td>
<td>39.3</td>
<td></td>
</tr>
<tr>
<td><strong>Age (years)</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>18–49</td>
<td>32 (20.8)</td>
<td>15.6</td>
<td>0.018</td>
</tr>
<tr>
<td>50–59</td>
<td>26 (16.9)</td>
<td>34.6</td>
<td></td>
</tr>
<tr>
<td>60–69</td>
<td>49 (31.8)</td>
<td>46.9</td>
<td></td>
</tr>
<tr>
<td>≥70</td>
<td>47 (30.5)</td>
<td>46.8</td>
<td></td>
</tr>
<tr>
<td><strong>Body mass index (kg/m²)</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Underweight/normal</td>
<td>53 (34.4)</td>
<td>26.4</td>
<td>0.117</td>
</tr>
<tr>
<td>Overweight</td>
<td>52 (33.8)</td>
<td>44.2</td>
<td></td>
</tr>
<tr>
<td>Obese</td>
<td>47 (30.5)</td>
<td>42.6</td>
<td></td>
</tr>
<tr>
<td>Missing</td>
<td>2 (1.3)</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Cigarette smoking status</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Current</td>
<td>10 (6.5)</td>
<td>30.0</td>
<td>0.675</td>
</tr>
<tr>
<td>Former</td>
<td>64 (41.6)</td>
<td>35.9</td>
<td></td>
</tr>
<tr>
<td>Never</td>
<td>77 (50.0)</td>
<td>41.6</td>
<td></td>
</tr>
<tr>
<td>Missing</td>
<td>3 (2.0)</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Alcohol/sedatives before</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Yes</td>
<td>126 (81.8)</td>
<td>38.1</td>
<td>0.798</td>
</tr>
<tr>
<td>No</td>
<td>27 (17.5)</td>
<td>40.7</td>
<td></td>
</tr>
<tr>
<td>Missing</td>
<td>1 (0.7)</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Self-reported diabetes</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>No diabetes</td>
<td>134 (87.0)</td>
<td>34.3</td>
<td>0.008</td>
</tr>
<tr>
<td>Diabetes</td>
<td>20 (13.0)</td>
<td>65.0</td>
<td></td>
</tr>
<tr>
<td><strong>Nasal breathing status</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>No difficulty</td>
<td>138 (89.6)</td>
<td>39.1</td>
<td>0.661</td>
</tr>
<tr>
<td>Difficulty</td>
<td>15 (9.7)</td>
<td>33.3</td>
<td></td>
</tr>
<tr>
<td>Missing</td>
<td>1 (0.7)</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Dry mouth</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>No dry mouth</td>
<td>115 (74.7)</td>
<td>31.3</td>
<td>0.002</td>
</tr>
<tr>
<td>Dry mouth</td>
<td>39 (25.3)</td>
<td>59.0</td>
<td></td>
</tr>
</tbody>
</table>

(a) The STOP questionnaire classifies persons as high risk for OSA with affirmative responses to ≥2 questions; low risk is defined as <2 affirmative responses

(b) World Health Organization International Classification: underweight (<18.50); normal (18.50–24.99); overweight (25.00–29.99); obese (≥30.00)
Table 4: Relationship of study participant characteristics and the presence of moderate or severe periodontitis.

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>N (%) with moderate or severe periodontitis</th>
<th>Odds ratio for moderate or severe periodontitis</th>
<th>95% CI</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total</td>
<td>50 (32.5)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Gender</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Female</td>
<td>27 (29.0)</td>
<td>Ref</td>
<td></td>
</tr>
<tr>
<td>Male</td>
<td>23 (37.7)</td>
<td>1.48</td>
<td>0.75, 2.93</td>
</tr>
<tr>
<td>Age (years)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>18–49</td>
<td>6 (18.8)</td>
<td>Ref</td>
<td></td>
</tr>
<tr>
<td>50–59</td>
<td>4 (15.4)</td>
<td>0.78</td>
<td>0.20, 3.15</td>
</tr>
<tr>
<td>60–69</td>
<td>13 (26.5)</td>
<td>1.56</td>
<td>0.52, 4.6</td>
</tr>
<tr>
<td>≥70</td>
<td>27 (57.5)</td>
<td>5.85</td>
<td>2.02, 16.87</td>
</tr>
<tr>
<td>Body mass index (kg/m²)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Underweight/normal</td>
<td>14 (26.4)</td>
<td>Ref</td>
<td></td>
</tr>
<tr>
<td>Overweight</td>
<td>17 (32.7)</td>
<td>1.35</td>
<td>0.58, 3.14</td>
</tr>
<tr>
<td>Obese</td>
<td>18 (38.3)</td>
<td>1.73</td>
<td>0.74, 4.04</td>
</tr>
<tr>
<td>Cigarette smoking status</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Current</td>
<td>5 (50.0)</td>
<td>2.35</td>
<td>0.62, 8.90</td>
</tr>
<tr>
<td>Former</td>
<td>22 (34.4)</td>
<td>1.23</td>
<td>0.60, 2.50</td>
</tr>
<tr>
<td>Never</td>
<td>23 (29.9)</td>
<td>Ref</td>
<td></td>
</tr>
<tr>
<td>Alcohol/sedatives before</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Yes</td>
<td>44 (34.9)</td>
<td>Ref</td>
<td></td>
</tr>
<tr>
<td>No</td>
<td>6 (22.2)</td>
<td>0.53</td>
<td>0.20, 1.42</td>
</tr>
<tr>
<td>Self-reported diabetes</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>No diabetes</td>
<td>96 (71.6)</td>
<td>Ref</td>
<td></td>
</tr>
<tr>
<td>Diabetes</td>
<td>8 (40.0)</td>
<td>3.79</td>
<td>1.44, 10.00</td>
</tr>
<tr>
<td>Nasal breathing status</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>No difficulty</td>
<td>49 (35.5)</td>
<td>Ref</td>
<td></td>
</tr>
<tr>
<td>Difficulty</td>
<td>1 (6.7)</td>
<td>0.13</td>
<td>0.02, 1.02</td>
</tr>
<tr>
<td>Dry mouth</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>No dry mouth</td>
<td>36 (31.3)</td>
<td>Ref</td>
<td></td>
</tr>
<tr>
<td>Dry mouth</td>
<td>14 (35.9)</td>
<td>1.23</td>
<td>0.57, 2.64</td>
</tr>
<tr>
<td>Educational attainment</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>&lt; College</td>
<td>29 (35.4)</td>
<td>Ref</td>
<td></td>
</tr>
<tr>
<td>≥ College</td>
<td>21 (29.2)</td>
<td>0.75</td>
<td>0.38, 1.49</td>
</tr>
<tr>
<td>Annual household income</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>&lt;50,000</td>
<td>28 (37.3)</td>
<td>Ref</td>
<td></td>
</tr>
<tr>
<td>≥50,000</td>
<td>15 (25.0)</td>
<td>0.56</td>
<td>0.26, 1.18</td>
</tr>
</tbody>
</table>

(a) World Health Organization International Classification: underweight (<18.50); normal (18.50–24.99); overweight (25.00–29.99); obese (≥30.00)
**Table 5:** Multivariate binary logistic regression modelling odds of moderate or severe periodontitis with 95% confidence interval (95% CI), (n=132)

<table>
<thead>
<tr>
<th></th>
<th>Odds ratio</th>
<th>95% CI</th>
</tr>
</thead>
<tbody>
<tr>
<td>Male gender (ref = female)</td>
<td>1.78</td>
<td>0.64, 4.94</td>
</tr>
<tr>
<td>Age in decades (a)</td>
<td>1.76</td>
<td>1.17, 2.64</td>
</tr>
<tr>
<td>Body mass index (continuous variable)</td>
<td>1.06</td>
<td>0.96, 1.16</td>
</tr>
<tr>
<td>Current smoker (ref = never smoked)</td>
<td>24.68</td>
<td>3.19, 191.20</td>
</tr>
<tr>
<td>Former smoker (ref = never smoked)</td>
<td>0.72</td>
<td>0.24, 2.11</td>
</tr>
<tr>
<td>Alcohol/sedative before bed (ref = no alcohol/sedative)</td>
<td>0.72</td>
<td>0.19, 2.71</td>
</tr>
<tr>
<td>Diabetes (ref = no diabetes)</td>
<td>2.70</td>
<td>0.64, 11.37</td>
</tr>
<tr>
<td>Nasal breathing difficulty (ref = no difficulty)</td>
<td>0.09</td>
<td>0.01, 0.88</td>
</tr>
<tr>
<td>Dry mouth (ref = no dry mouth)</td>
<td>0.36</td>
<td>0.10, 1.39</td>
</tr>
<tr>
<td>Educational attainment ≥ college (ref = &lt;college)</td>
<td>0.63</td>
<td>0.22, 1.82</td>
</tr>
<tr>
<td>Annual household income ≥$50,000 (ref = &lt;$USD$50,000)</td>
<td>0.63</td>
<td>0.24, 1.63</td>
</tr>
<tr>
<td>High risk for obstructive sleep apnea on STOP questionnaire (ref = low risk)</td>
<td>4.11</td>
<td>1.48, 11.45</td>
</tr>
<tr>
<td>Constant</td>
<td>0.00</td>
<td>0.00, 0.18</td>
</tr>
</tbody>
</table>

(a) Age measured in years is not substantively meaningful; hence age was rescaled in units of 10 to denote decade-sized units.
**APPENDICES**  
Appendix I

**Periodontal Case Type Definition**

<table>
<thead>
<tr>
<th>Healthy Periodontium, Type N</th>
<th>Gingivitis Type I</th>
<th>Slight* Periodontitis Type II</th>
<th>Moderate Periodontitis Type III</th>
<th>Severe Periodontitis Type IV</th>
</tr>
</thead>
<tbody>
<tr>
<td>- no alveolar bone loss</td>
<td>- no alveolar bone loss</td>
<td>- slight attachment loss</td>
<td>- moderate alveolar bone and attachment loss</td>
<td>- severe alveolar bone and attachment loss</td>
</tr>
<tr>
<td>- healthy gingiva and</td>
<td>- bleeding and/or suppuration may be present</td>
<td>- slight bone loss is evident, especially in alveolar crest</td>
<td>- 5-6 mm probing depths</td>
<td>- 7+ mm probing depths</td>
</tr>
<tr>
<td>alveolar bone level</td>
<td>- 2-3 mm probing depths</td>
<td>- 3-4 mm probing depths</td>
<td></td>
<td></td>
</tr>
<tr>
<td>- no bleeding</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>- 1-2 mm probing depths</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>- no clinical attachment loss (CAL)</td>
<td>- no clinical attachment loss (CAL)</td>
<td>1-2 mm clinical attachment loss (CAL)</td>
<td>3-4 mm clinical attachment loss (CAL)</td>
<td>Greater than or equal to 5mm clinical attachment loss (CAL)</td>
</tr>
<tr>
<td>- no mobility</td>
<td>- no mobility</td>
<td>- no mobility</td>
<td>- mobility is possible</td>
<td>- mobility is possible</td>
</tr>
<tr>
<td>- no furcation</td>
<td>- no furcation</td>
<td>- no furcation</td>
<td>- furcation involvement is possible</td>
<td>- furcation involvement is possible</td>
</tr>
</tbody>
</table>

Please Note: Periodontal classification is based on clinical and radiographic findings. Findings must be generalized in order to be classified in a higher case type. **localized: < 30% of sites involved**  **generalized: ≥ 30% of sites involved**

* Note that the American Dental Association (ADA) uses the term “early” in the definition of case-type II periodontitis, where the School of Dentistry at the University of North Carolina at Chapel Hill uses the term “slight” in the definition of case-type II periodontitis.
Appendix II

University of North Carolina-Chapel Hill
Information about a Research Study

IRB Study # 10-2326   Consent Form Version Date:
Title of Study: Risks of Obstructive Sleep Apnea Upon Screening in a Dental 
Hygiene Preventive Care Clinic (Clinic Patient)

Principal Investigator: Nuha E. Ahmad
UNC-Chapel Hill Department: School of Dentistry
Faculty Advisor: Dr. Gregory Essick, DDS, PhD
Department of Prosthodontics
CB #: 7450, Chapel Hill, NC 27599-7450
Phone #: (919) 966-9782
E-mail: essickg@dentistry.unc.edu

Study Contact telephone number: 703-623-3046
Study Contact email: neahmad@dentistry.unc.edu

What are some general things you should know about research studies?
You are being asked to take part in a research study. To be included the study is voluntary.
You may refuse to join, or you may withdraw your consent to be in the study, for any reason,
without penalty.
Research studies are designed to obtain new knowledge. This new information may help
people in the future. You may not receive any direct benefit from being in the research
study. Participation in this research study does not entail any additional risk to your
appointment for dental cleaning.
Details about this study are discussed below. It is important that you understand this
information so that you can make an informed choice about being in this research study.
You will be given a copy of this consent form. You should ask the researchers named above,
or staff members who may assist them, any questions you have about this study at any time.

What is the purpose of this study?
Obstructive sleep apnea is becoming a very common disorder that affects many aspects of a
person’s life and well-being. The majority of people having obstructive sleep apnea are not
aware of it. We are aiming to train dental hygienists to screen their patients for the possibility
of being at risk of having obstructive sleep apnea during their patients’ routine checkups. We
are also interested in findings from the face, mouth, and teeth that might be related to the
increased risk of obstructive sleep apnea.

How many people will take part in this study?
If you decide to be in this study, you will be one of approximately 200 people in this research
study.
How long will your part in this study last?
You will be asked to fill out a questionnaire that should not take you longer than 10 minutes. And the questionnaire filled by the hygienist will take no longer than 5 minutes.

What will happen if you take part in the study?
You will fill out a questionnaire addressing some personal data and your sleeping habits. The hygienist will fill out another questionnaire regarding some findings from your face, mouth and teeth, most of which is normally assessed through your appointment. You do not have to answer any questions that you do not wish to answer, for any reason.

What are the possible benefits from being in this study?
Research is designed to benefit society by gaining new knowledge. Your participation is important to help us understand the factors influencing the possibility of having obstructive sleep apnea. The hygienist will be able to assess your risk of having obstructive sleep apnea by calculating a risk score from data in the questionnaires. This score is obtained according to the STOP-Bang validated questionnaire. There is no cost to you for participating in this research study other than time.

What are the possible risks or discomforts involved from being in this study?
We do not think you will experience any discomfort or risk from this study.

How will your privacy be protected?
No personal identifying information that you provide, such as your name, address, phone number, or medical file number will be on the questionnaires or kept as part of this research. All completed questionnaires will be kept in a file cabinet in a locked office, and computer data will be kept on a computer with a secured network and password protected.

Will you receive anything for being in this study?
There is no compensation for participating in this study, however, your information is very important to us.

Will it cost you anything to be in this study?
There are no costs for being in the study.

What if you have questions about this study?
You have the right to ask, and have answered, any questions you may have about this research. If you have questions, or concerns, you can ask you hygienist at the time of your visit. You can also contact me or my advisor at the phone numbers and email addresses listed at the beginning of this form.

What if you have questions about your rights as a research participant?
All research on human volunteers is reviewed by a committee that works to protect your rights and welfare. If you have questions or concerns about your rights as a research subject you may contact, anonymously if you wish, the Institutional Review Board at 919-966-3113 or by email to IRB_subjects@unc.edu.

Thank you for helping me with this study.
### Appendix III

**UNC DEPARTMENT OF DENTAL HYGIENE**  
Screening for OSA in a Dental Hygiene Preventive Care Clinic

### Patient Questionnaire

**INSTRUCTIONS:** Please use pen to complete form. Fill in circles completely for the most appropriate option or fill in the blanks as needed. Please fill in only ONE option for each question unless otherwise specified.

<table>
<thead>
<tr>
<th>Gender:</th>
<th>Male</th>
<th>Female</th>
<th>Age:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Weight:</td>
<td></td>
<td>pounds</td>
<td>kgs</td>
</tr>
<tr>
<td>Height:</td>
<td></td>
<td>inches</td>
<td>cms</td>
</tr>
</tbody>
</table>

What is your average annual household income?  
- Less than $35,000
- $35,000 - $49,999
- $50,000 - $74,999
- $75,000 or above

What is your highest educational level?  
- Did not complete high school
- High school completed or graduate-equivalent diploma received
- Community college, technical school, or some college completed
- Completed college
- Have more than one degree from college

1. Do you snore loudly (louder than talking or loud enough to be heard through closed doors)?  
- Yes, but not that loud
- Yes, louder than talking or could be heard through closed doors
- I don’t snore
- I don’t know

2. Do you often feel tired, fatigued, or sleepy during the day?  
- Yes
- No

3. Has anyone observed you stop breathing during your sleep?  
- Yes
- No
- No, but no one observes me sleeping

4. Please rate the chances of you dozing during the day in the different situations listed below according to Epworth Sleepiness Scale.

<table>
<thead>
<tr>
<th>Situation</th>
<th>Would never doze</th>
<th>Slight chance of dozing</th>
<th>Moderate chance of dozing</th>
<th>High chance of dozing</th>
</tr>
</thead>
<tbody>
<tr>
<td>a. Sitting and reading</td>
<td>◯</td>
<td>◯</td>
<td>◯</td>
<td>◯</td>
</tr>
<tr>
<td>b. Watching television</td>
<td>◯</td>
<td>◯</td>
<td>◯</td>
<td>◯</td>
</tr>
<tr>
<td>c. Sitting inactive in a public place, for example, a theater or meeting</td>
<td>◯</td>
<td>◯</td>
<td>◯</td>
<td>◯</td>
</tr>
<tr>
<td>d. As a passenger in a car for an hour without a break</td>
<td>◯</td>
<td>◯</td>
<td>◯</td>
<td>◯</td>
</tr>
<tr>
<td>e. Laying down to rest in the afternoon</td>
<td>◯</td>
<td>◯</td>
<td>◯</td>
<td>◯</td>
</tr>
<tr>
<td>f. Still and talking to someone</td>
<td>◯</td>
<td>◯</td>
<td>◯</td>
<td>◯</td>
</tr>
<tr>
<td>g. Sitting quietly after lunch (When you have had no alcohol)</td>
<td>◯</td>
<td>◯</td>
<td>◯</td>
<td>◯</td>
</tr>
<tr>
<td>h. In a car, while stopped in traffic</td>
<td>◯</td>
<td>◯</td>
<td>◯</td>
<td>◯</td>
</tr>
</tbody>
</table>

Revised 10/2010
12. If a physician has diagnosed you with OSA, what treatments have you tried? (Please choose ALL that apply)
   - Positional therapy (sleep on side only)
   - Behavioral therapy (for example, reduce alcohol consumption before bed time)
   - Weight loss program or recommendation
   - Use of nasal continuous positive airway pressure (CPAP)
   - Surgery (please specify) ____________________________
   - Oral appliance for teeth
   - Oral appliance for tongue only
   - Other (please specify) ____________________________
   - Not applicable

13. If you have been diagnosed with OSA by a physician, what treatments are you currently using? (Please choose ALL that apply)
   - Positional therapy (sleep on side only)
   - Behavioral therapy (for example, reduce alcohol consumption before bed time)
   - Weight loss program or recommendation
   - Use of nasal continuous positive airway pressure (CPAP)
   - Surgery (please specify) ____________________________
   - Oral appliance for teeth
   - Oral appliance for tongue only
   - Other (please specify) ____________________________
   - Not applicable
Appendix IV

UNC DEPARTMENT OF DENTAL HYGIENE
Screening for OSA in a Dental Hygiene Preventive Care Clinic
Dental Hygiene Student’s Clinical Observations Questionnaire

INSTRUCTIONS: Please use pen to complete form. Fill in circles completely for the most appropriate option or fill in the blanks as needed. Please fill in only ONE option for each question unless otherwise specified.

<table>
<thead>
<tr>
<th>Blood Pressure:</th>
<th>BMI:</th>
<th>Neck Circumference:</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

1. Body Mass Index (BMI) more than 35 kg/m²?  ○ Yes  ○ No

2. Age, Over 50 years old?  ○ Yes  ○ No

3. Neck Circumference, greater than 40 cm?  ○ Yes  ○ No

4. Gender, male?  ○ Yes  ○ No

5. Does the patient have dry mouth?  ○ Yes, not related to medications he/she is using  ○ Yes, likely a side effect of a medication he/she is using  ○ No

6. Does the patient have macroglossia (large tongue)? (Please choose ALL that apply)
   ○ Yes, lateral borders of the tongue are ridged
   ○ Yes, lateral borders of the tongue lay across occlusal surfaces of the molars
   ○ Yes, the tongue lay on the incisal surfaces on the anterior teeth
   ○ No

7. What is the patient’s Mallampati score?  ○ A  ○ B  ○ C  ○ D

8. What is the patient’s tonsil grade?  ○ A  ○ B  ○ C  ○ D  ○ E

A. Patient had tonsillectomy
B. Tonsils are in the tonsillar fossa, barely seen behind the anterior pillars
C. Tonsils are visible behind the anterior pillars
D. Tonsils are extended 3/4 of the way to the midline
E. Tonsils are completely obstructing the airway, "kissing tonsils"

Revised 10/2010
9. How does the maxillary arch appear?
   - A. U-shaped, with normally arched palate
   - B. Square or Broad, with low lying palate
   - C. V-shaped or narrow, with high vaulted palate

10. What is the patient's attrition's rate according to Basic Erosive Wear Examination scores per sextant?

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>0 = No erosive tooth wear</td>
<td>1 = Initial loss of surface texture</td>
<td>2* = Distinct defect, hard tissue loss &lt; 50% of the surface area</td>
<td>3* = Hard tissue loss &gt; 50% of the surface area</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

* In scores 2 and 3, dentine is often involved

11. What is the patient's over-jet?
   - Under-jet (anterior cross bite)
   - 0 mm
   - 1 mm
   - 2 mm
   - 3 mm
   - 4 mm
   - > 4 mm

12. What is the patient's plaque index?
   - 0
   - 0 = No erosive tooth wear
   - 1
   - 2
   - 3
   - > 4 mm

13. What is the patient's gingival index?
   - 0
   - 0 = No erosive tooth wear
   - 1
   - 2
   - 3

14. What is the patient's bleeding index?
   - 0
   - 0 = No erosive tooth wear
   - 1
   - 2
   - 3
   - 4
   - 5

15. How many sites with periodontal pocket depths of:
   - a. PPD = 4 mm
     - 0
     - 1
     - 2
     - 3
     - 4
     - 5
     - 6
     - 7
     - > 7
   - b. PPD = 5 mm
     - 0
     - 1
     - 2
     - 3
     - 4
     - 5
     - 6
     - 7
     - > 7
   - c. PPD > 5 mm
     - 0
     - 1
     - 2
     - 3
     - 4
     - 5
     - 6
     - 7
     - > 7

16. How many sites with recession of:
   - a. REC = 1 mm
     - 0
     - 1
     - 2
     - 3
     - 4
     - 5
     - 6
     - 7
     - > 7
   - b. REC = 2 mm
     - 0
     - 1
     - 2
     - 3
     - 4
     - 5
     - 6
     - 7
     - > 7
   - c. REC > 3 mm
     - 0
     - 1
     - 2
     - 3
     - 4
     - 5
     - 6
     - 7
     - > 7
   - d. REC = 4 mm
     - 0
     - 1
     - 2
     - 3
     - 4
     - 5
     - 6
     - 7
     - > 7
   - e. REC > 4 mm
     - 0
     - 1
     - 2
     - 3
     - 4
     - 5
     - 6
     - 7
     - > 7

17. What is the patient's periodontal case type?
   - I
   - II
   - III
   - IV


58. Enciso R, Clark GT. Comparing the berlin and the ARES questionnaire to identify patients with obstructive sleep apnea in a dental setting. Sleep Breath. 2010 Feb 2


80. Mehra R, Benjamin EJ, Shahar E, Gottlieb DJ, Nawabit R, Kirchner HL, Sahadevan J, Redline S, Sleep Heart Health Study. Association of nocturnal arrhythmias with sleep-


120. Beebe DW, Ris MD, Kramer ME, Long E, Amin R. The association between sleep disordered breathing, academic grades, and cognitive and behavioral functioning among overweight subjects during middle to late childhood. Sleep. 2010 Nov;33(11):1447-56.
