Dental Arch Width and Length Parameters in Patients with Obstructive Sleep Apnea vs Patients Without: A Pilot Study

THESIS

Presented in Partial Fulfillment of the Requirements for the Degree Master of Science in the Graduate School of The Ohio State University

By

James Martin Sacksteder, DDS
Graduate Program in Dentistry

The Ohio State University
2017

Master's Examination Committee:

Dr. Allen Firestone, Advisor
Dr. Do-Gyoon Kim
Dr. Frank Beck
Dr. Ulysses Magalang
Abstract

**Objective:** Limited data suggests a smaller, narrow maxilla can lead to a decreased oropharyngeal volume (OPV). However, past studies have used 2-dimensional (2D) lateral cephalometric radiographs. The specific aim of this study is to assess how maxillary arch parameters relate to oropharyngeal volume calculated from 3D cone beam computed tomography (CBCT) images. An additional aim was to compare these dimensions in a group of African-American patients with obstructive sleep apnea (OSA) with a group of healthy controls.

**Methods:** 16 full head CBCT images in the closed mouth anatomic head position were obtained from adult male African-American patients with a diagnosis of OSA. The OPV was measured by counting corresponding voxels that are digitally isolated from the 3D CBCT images after segmentation. The same volume axial plane images were used to measure intercanine width, intermolar width, arch length and arch perimeter. In addition, 16 control CBCT images were obtained from adult male African-American patients matched for age with no prior diagnosis of OSA. Each of the maxillary arch parameters was tested for correlation to oropharyngeal volume and compared between the two groups.

**Results:** Reliability was tested and for all parameters the intraclass correlation coefficient was greater than 0.95 (0.97-1.00). The OSA group was significantly older than controls.
(31.9±6.9, 41.3±11.3 years respectively). After accounting for multiple comparisons the minimum cross sectional area (MINXA) was the only parameter significantly different between groups (p=0.0014). MINXA was found to be a good-excellent predictor of OSA (Receiver operating characteristic curve area under curve =0.89). A cutpoint of 111mm$^2$ was determined for MINXA between groups.

**Conclusion:** The CBCT based imaging analysis produces reliable measurements for all parameters. The current finding suggest that maxillary arch width and length do not contribute to a smaller oropharyngeal airway. MINXA is a good-excellent predictor of OSA in African American adult males.
Dedication

This document is dedicated to my loving and supportive family and friends.
Vita

June 2005 .............................................................St. Wendelin High School

2009 ...............................................................B.S. Biology, Ohio University

2014 .................................................................D.D.S. The Ohio State University

2014 to present ....................................................Resident and Graduate Teaching Associate,

Department of Orthodontics, The Ohio State

University

Publications


Fields of Study

Major Field: Dentistry

Specialty: Orthodontics
# Table of Contents

Abstract ........................................................................................................ ii

Dedication ....................................................................................................... iv

Vita................................................................................................................ v

List of Tables ................................................................................................ vii

List of Figures ............................................................................................... viii

Chapters:

1. Introduction.................................................................................................1

2. Methods and Materials..............................................................................6

3. Manuscript..................................................................................................10

4. Conclusions.................................................................................................30

Bibliography .................................................................................................37
List of Tables

Table 1 Parameters to be measured................................................................. 17

Table 2 Reliability of Each Measurement Parameter $^a$................................. 20

Table 3 Descriptive statistics for control and OSA group $^a$............................. 21

Table 4 $P$ values .............................................................................................. 21
List of Figures

**Figure 1** Receiver operating characteristic curve for airway volume .......................... 23

**Figure 2** Receiver operating characteristic curve for intermolar width .......................... 24

**Figure 3** Receiver operating characteristic curve for minimum cross sectional area ..... 25

**Figure 4** Composite receiver operating characteristic curve for AWV, IMW and MXSAREA ........................................................................................................................................ 26
CHAPTER 1

INTRODUCTION

Obstructive sleep apnea (OSA) is a common disorder in which a person stops breathing (apnea), or has a reduced air volume into the lungs (hypopnea) during sleep. The obstruction occurs due to the collapse of the upper airway. This disorder is increasing in prevalence as the population increases in weight, the percentage of older individuals in the population increases, and is being diagnosed more frequently as doctors become more aware of the disease. As of 2002 OSA syndrome (ie, an apnea-hypopnea index (AHI) >5 with excessive daytime sleepiness) was believed to affect 2-4% of the population\(^1\). Today we now estimate OSA affects 14% of men and 5% of women\(^2\).

Sleep apnea is associated with significant health problems, psychological and physiological. Patients with untreated OSA are at an increased risk for stroke, diabetes, heart failure, irregular heartbeat, myocardial infarction, and hypertension\(^3\); due not only to lack of oxygenation, but also to increased sympathetic activity\(^1\). Psychological deficits associated with untreated OSA include depression, anxiety, daytime sleepiness, and increased risk of motor vehicle accidents.

There are many factors that are associated with increased risk of developing obstructive sleep apnea. These include overweight, a large neck size (17 inches in males,
16 in females), large tonsils or tongue, a decreased mandibular body length, increased mandibular plane to hyoid bone distance, family history, and being male. However, not all patients with sleep apnea are the stereotypical obese middle aged male. For that reason it is important to identify other clinical conditions that will indicate with a high degree of accuracy that the individual has a high probability of having (or developing) obstructive sleep apnea.

Previous studies to see if there were indicators of increased risk for obstructive sleep apnea in an individual’s cranio-facial dimensions have generally been performed on two-dimensional lateral cephalometric radiographs. One significant limitation to this method of inquiry is the complex three-dimensional geometry of the airway that cannot be completely evaluated from a two-dimensional image. Current advances in computed tomography imaging allow the visualization and analysis of craniofacial structures in three dimensions. The use of cone beam computed tomography (CBCT) has been shown to be accurate and reliable in assessing airway volume. Further studies to examine cranio-facial structures and dimensions would be more informative if they were to utilize data from three-dimensional imaging.

First developed in the 1980’s CBCT became commercially available to the European market in 1996 and subsequently the US market in 2001. Prior to its advent airway analysis was performed via 2D lateral cephalometric radiographs, magnetic resonance imaging (MRI), multiple detector computed tomography (MDCT), and endoscopy. These imaging techniques come with the increased challenge of high cost,
low availability and in the case of CT, high radiation dose exposure. CBCT has been used to analyze airway as early as 2006. In discriminating between soft tissue structures CBCT is inferior to MDCT, but is able to define the boundaries between soft tissues and empty spaces with high spatial resolution. This method has been shown to be accurate and reproducible in addition to its other advantages of being easily accessible, requiring a shorter acquisition time, lower effective radiation dose, and lower cost when compared to MRI or CT.

As OSA is frequently the result of a neuro-muscular anatomic condition in the oro-pharyngeal area investigators have looked at the volume of the oral cavity and possible risk factors. The effects of extraction for orthodontic reasons on oral and pharyngeal dimensions has been the subject of several investigations. A study by Valiathana et al found no significant difference in oropharyngeal airway dimensions between adolescent patients with and without extractions during orthodontic treatment. Pliska et al reported similar findings in a group of non-growing adult patients. However, Wang et al reported that extraction of four premolars with retraction of the incisors decreased pharyngeal dimensions. The results of this latter study agree with those reported by Germec-Cakan et al, and taken together these studies suggest that decreasing the arch length can result in less space in the oral cavity for the tongue. The argument is that the tongue in turn will move posteriorly encroaching on the oropharyngeal airway space and reducing airway volume. When Seto and coworkers looked at maxillary morphology in OSA patients versus controls, they reported that OSA
patients had narrower, more tapered, and shorter maxillary arches than non-apnea controls. However, a study by Rush et al. revealed no association between extraction of teeth and a diagnosis of OSA.

Evidence suggests ethnicity may be a risk factor for OSA. Sutherland et al reported very similar rates of OSA prevalence for populations around the world\textsuperscript{15}. This finding is surprising given the different obesity rates, demographics and variations in craniofacial structure found in different ethnicities. The contribution to OSA will vary between ethnicities with respect to upper airway soft tissues, obesity, and craniofacial bony dimensions. One study suggests that African Americans with OSA have a larger contribution of soft tissue enlargement\textsuperscript{16}. This is in contrast to Caucasians having a contribution from both soft tissue and skeletal characteristics. Asians have been found to have a larger contribution form skeletal restriction. It is clear that understanding ethnicity-specific craniofacial risk factors is particularly important.

There is a deficiency in knowledge concerning dental parameters of OSA. These parameters have never been studied in an African American population. The aim of this study was to compare dental parameters which contribute to size of the oral cavity in a group of African American patients diagnosed with OSA with a control group. The aim was to investigate if these arch parameters (length and width) relate to oropharyngeal volume calculated from a three dimensional CBCT image in African American subjects.
HYPOTHESES

H₀₁: Obstructive sleep apnea patients do not have shorter dental arches than a control group matched for age, sex and ethnicity.

H₀₂: Obstructive sleep apnea patients do not have dental arches that are narrower (in terms of intercanine and intermolar width) than a control group matched for age and ethnicity.

H₀₃: There is no correlation between intercanine distance, intermolar width, arch perimeter, number of teeth from first molar to central incisor or arch length and oropharyngeal airway volume or minimum cross sectional area.
CHAPTER 2

MATERIALS & METHODS

A sample of CBCT images taken on adult African American patients with diagnosed obstructive sleep apnea were obtained from an existing database in DICOM format after identifying information had been removed. Twenty one (21) images were initially included in this database. The images from this sample make up the Obstructive Sleep Apnea group (OSA Group). A control group was obtained by applying screening criteria to all CBCT images taken within the Ohio State University College of Dentistry from 2009 to June 2016. Inclusion criteria for the control group were males of at least 18 years of age, no known diagnosis of OSA, and full head CBCT images taken in the closed mouth anatomical head position (not supine). Exclusion criteria for both groups included missing maxillary canines or first molars, or pathology/artifacts in the area of interest. The Institutional Review Board (IRB) at The Ohio State University approved the study protocol (protocol #2016H0008).

All CBCT scans were taken using an i-CAT Next Generation Platinum CBCT unit (Imaging Sciences International, Hatfield Pa). At the time of image acquisition no instructions were given to patents regarding tongue position or breathing. The only instructions given were to remain still and breathe through nose while holding teeth gently together. All Digital Imaging and Communications in Medicine (DICOM) files
were imported into an imaging analysis program (Dolphin Imaging, version 11.9 Premium; Dolphin Imaging and Management Solutions, Chatsworth, California) for this study. Once imported, the 3-dimensional images were all standardized in orientation consistent with a method used by Pliska et al.\textsuperscript{12}. The midsagittal plane was determined from the skeletal midline using a line connecting nasion to opisthion. Coronal plane was determined to be perpendicular to Frankfort horizontal. The axial plane was determined by a line connecting the inferior borders of the left and right orbit parallel to the horizontal grid.

Each measurement was performed by a single blinded rater. Prior to study initiation a sample of ten (10) images were measured. After two weeks the same images were re-measured to calculate reliability of the measurement method. Measurement parameters were determined as follows:

**Intercanine Width:** Distance from the incisal tip of the cusp of a maxillary canine to the contralateral.

**Intermolar width:** Distance from the mesiolingual cusp tip of a maxillary first molar to the same point on the contralateral molar.

**Arch length:** Perpendicular distance from a point between the central incisors to a line connecting the mesial contacts of the first permanent molars.

**Arch Perimeter:** Distance from the mesial contact of one first permanent molar to its antimere as measured through the contact points, buccal cusp tips, and incisal edges of all of the intervening teeth, ignoring those teeth that are
malpositioned or blocked out so that the measurement represents an ideal arch form.

**Upper airway volume:** The space occupied by air in the oral cavity, nasal passages and area behind the tongue superior to the epiglottis. For this study we will only be looking at the oropharyngeal volume. The superior limit is a line from the posterior nasal spine (PNS) to the most superior aspect of the odontoid process of the axis (C2), as done in the study by Glupker et al\(^\text{18}\). The inferior limit is the most superior aspect of the epiglottis which is the anatomical boundary of the oropharynx.

**Minimum cross sectional airway:** The most constricted portion of the airway as measured in square millimeters parallel with the axial plane.

Airway volume and minimum cross sectional area were calculated using the sinus/airway tool in the Imaging software\(^\text{17}\). The boundaries for oropharyngeal volume are consistent with those used in a study by Glupker et al\(^\text{18}\). The superior boundary is defined by a line connecting the posterior nasal spine (PNS) anteriorly and the most superior aspect of the odontoid process of the axis (C2) posteriorly. The inferior limit of the oropharyngeal volume is a line at the tip of the epiglottis extending anteriorly and posteriorly parallel with the horizontal axis. A threshold method was used to segment the airway. The airway sensitivity tool was adjusted to eliminate imaging artifacts and ranged from 50-75. Airway volume was calculated in cubic millimeters and the minimum axial area in square millimeters.
Isolation of the 3-dimensional maxillary arch was done by using the software ‘Clipping Slice’ tool to remove all structures below the occlusal plane. The software ‘Digitize/Measure’ tool with the 2D line tab selected was used to measure the maxillary arch parameters. The intercanine width was measured from the cusp tip of one maxillary canine to its contralateral. Mesiolingual cusp tip of the maxillary first molar was used for intermolar width. The arch length was found by first drawing a line connecting the mesial contact points of the maxillary first molars. The midline point of this line was connected to a point on the same plane at the most facial portion of the maxillary incisor. Arch perimeter was found by measuring from the mesial contact point of the first molar to its antimere as measured through the contact points of posterior teeth and incisal edges of anterior teeth ignoring those teeth that were malpositioned or blocked out so that the measurement represents an ideal arch form.
CHAPTER 3

MANUSCRIPT

Dental Arch Width and Length Parameters in Patients with Obstructive Sleep Apnea vs Patients Without: A Pilot Study

ABSTRACT

Objective: Limited data suggests a smaller, narrow maxilla can lead to a decreased oropharyngeal volume (OPV). However, past studies have used 2-dimensional (2D) lateral cephalometric radiographs. The specific aim of this study is to assess how maxillary arch parameters relate to oropharyngeal volume calculated from 3D cone beam computed tomography (CBCT) images. An additional aim was to compare these dimensions in a group of African-American patients with obstructive sleep apnea (OSA) with a group of healthy controls.

Methods: 16 full head CBCT images in the closed mouth anatomic head position were obtained from adult male African-American patients with a diagnosis of OSA. The OPV was measured by counting corresponding voxels that are digitally isolated from the 3D CBCT images after segmentation. The same volume axial plane images were used to measure intercanine width, intermolar width, arch length and arch perimeter. In addition,
16 control CBCT images were obtained from adult male African-American patients matched for age with no prior diagnosis of OSA. Each of the maxillary arch parameters was tested for correlation to oropharyngeal volume and compared between the two groups.

**Results:** Reliability was tested and for all parameters the intraclass correlation coefficient was greater than 0.95 (0.97-1.00). The OSA group was significantly older than controls (31.9±6.9, 41.3±11.3 years respectively). After accounting for multiple comparisons the minimum cross sectional area (MINXA) was the only parameter significantly different between groups (p=0.0014). MINXA was found to be a good-excellent predictor of OSA (Receiver operating characteristic curve area under curve =0.89). A cutpoint of 111mm$^2$ was determined for MINXA between groups.

**Conclusion:** The CBCT based imaging analysis produces reliable measurements for all parameters. The current finding suggest that maxillary arch width and length do not contribute to a smaller oropharyngeal airway. MINXA is a good-excellent predictor of OSA in African American adult males.
INTRODUCTION

Obstructive sleep apnea (OSA) is a common disorder in which a person stops breathing (apnea), or has a reduced air volume into the lungs (hypopnea) during sleep. The obstruction occurs due to the collapse of the upper airway. This disorder is increasing in prevalence as the population increases in weight, the percentage of older individuals in the population increases, and is being diagnosed more frequently as doctors become more aware of the disease. As of 2002 OSA syndrome (an apnea-hypopnea index (AHI) >5 with excessive daytime sleepiness) was believed to affect 2-4% of the population. Today we now estimate OSA affects 14% of men and 5% of women.

Sleep apnea is associated with significant health problems, psychological and physiological. Patients with untreated OSA are at an increased risk for stroke, diabetes, heart failure, irregular heartbeat, myocardial infarction, and hypertension; due not only to lack of oxygenation, but also to increased sympathetic activity. Psychological deficits associated with untreated OSA include depression, anxiety, daytime sleepiness, and increased risk of motor vehicle accidents.

There are many factors that are associated with increased risk of developing obstructive sleep apnea. These include overweight, a large neck size (17 inches in males, 16 in females), large tonsils or tongue, a decreased mandibular body length, increased mandibular plane to hyoid bone distance, family history, and being male. However, not
all patients with sleep apnea are the stereotypical obese middle aged male\textsuperscript{5,6}. For that reason it is important to identify other clinical conditions that will indicate with a high degree of accuracy that the individual has a high probability of having (or developing) obstructive sleep apnea.

Previous studies to see if there were indicators of increased risk for obstructive sleep apnea in an individual’s cranio-facial dimensions have generally been performed on two-dimensional lateral cephalometric radiographs. One significant limitation to this method of inquiry is the complex three-dimensional geometry of the airway that cannot be completely evaluated from a two-dimensional image. Current advances in computed tomography imaging allow the visualization and analysis of craniofacial structures in three dimensions. The use of cone beam computed tomography (CBCT) has been shown to be accurate and reliable in assessing airway volume\textsuperscript{7}. Further studies to examine cranio-facial structures and dimensions would be more informative if they were to utilize data from three-dimensional imaging.

First developed in the 1980’s CBCT became commercially available to the European market in 1996 and subsequently the US market in 2001\textsuperscript{8}. Prior to its advent airway analysis was performed via 2D lateral cephalometric radiographs, magnetic resonance imaging (MRI), multiple detector computed tomography (MDCT), and endoscopy. These imaging techniques come with the increased challenge of high cost, low availability and in the case of CT, high radiation dose exposure. CBCT has been used to analyze airway as early as 2006. In discriminating between soft tissue structures
CBCT is inferior to MDCT, but is able to define the boundaries between soft tissues and empty spaces with high spatial resolution\(^9\). This method has been shown to be accurate and reproducible in addition to its other advantages of being easily accessible, requiring a shorter acquisition time, lower effective radiation dose, and lower cost when compared to MRI or CT.

As OSA is frequently the result of a neuro-muscular anatomic condition in the oro-pharyngeal area\(^{10}\) investigators have looked at the volume of the oral cavity and possible risk factors. The effects of extraction for orthodontic reasons on oral and pharyngeal dimensions has been the subject of several investigations. A study by Valiathana et al found no significant difference in oropharyngeal airway dimensions between patients with and without extractions during orthodontic treatment\(^{11}\). Pliska et al agreed with this finding in a group of non-growing adult patients\(^{12}\). However, Wang et al reported that extraction of four premolars with retraction of the incisors did decrease pharyngeal dimensions\(^{13}\). The results of this latter study agree with those reported by Germec-Cakan et al\(^{14}\), and taken together these studies suggest that decreasing the arch length can result in less space for the tongue. The tongue in turn will move posteriorly encroaching on the oropharyngeal airway space and reducing airway volume. When Seto\(^4\) and coworkers looked at maxillary morphology in OSA patients versus controls, they reported that OSA patients had narrower, more tapered, and shorter maxillary arches than non-apnea controls.
Evidence suggests ethnicity may be a risk factor for OSA. Sutherland et al reported very similar rates of OSA prevalence for populations around the world\(^\text{15}\). This finding is surprising given the different obesity rates, demographics and variations in craniofacial structure found in different ethnicities. The contribution to OSA will vary between ethnicities with respect to upper airway soft tissues, obesity, and craniofacial bony dimensions. One study suggests that African Americans with OSA have a larger contribution of soft tissue enlargement\(^\text{16}\). This is in contrast to Caucasians having a contribution from both soft tissue and skeletal characteristics. Asians have been found to have a larger contribution from skeletal restriction. It is clear that understanding ethnicity-specific craniofacial risk factors is particularly important.

There is a deficiency in knowledge concerning dental parameters of OSA. These parameters have never been studied in an African American population. We propose to compare dental parameters which contribute to size of the oral cavity in a group of African American patients diagnosed with OSA with a control group matched for age and gender. The aim is to see how these arch parameters (length and width) relate to oropharyngeal volume calculated from a three dimensional CBCT image in African American subjects.
MATERIALS AND METHODS

A sample of CBCT images taken on adult African American patients with diagnosed obstructive sleep apnea were obtained from an existing database in DICOM format after identifying information had been removed. Twenty seven (27) images were initially included in this database. The images from this sample make up the Obstructive Sleep Apnea group (OSA Group). A control group was obtained by applying screening criteria to all CBCT images taken within the Ohio State University College of Dentistry from 2009 to June 2016. Inclusion criteria for the control group were males of at least 18 years of age, no known diagnosis of OSA, and full head CBCT images taken in the closed mouth anatomical head position (not supine). Exclusion criteria for both groups included missing maxillary canines or first molars, or pathology/artifacts in the area of interest. The Institutional Review Board (IRB) at The Ohio State University approved the study protocol (protocol #2016H0008).

All CBCT scans were taken using an i-CAT Next Generation Platinum CBCT unit (Imaging Sciences International, Hatfield Pa). At the time of image acquisition no instructions were given to patients regarding tongue position or breathing. The only instructions given were to remain still and breathe through nose while holding teeth gently together. All DICOM files were imported into an imaging analysis program (Dolphin Imaging, version 11.9 Premium; Dolphin Imaging and Management Solutions,
Chatsworth, California) for this study. Once imported, the 3-dimensional images were all standardized in orientation consistent with a method used by Pliska et al.\textsuperscript{12}. The midsagittal plane was determined from the skeletal midline using a line connecting nasion to opisthion. Coronal plane was determined to be perpendicular to Frankfort horizontal. The axial plane was determined by a line connecting the inferior borders of the left and right orbit parallel to the horizontal grid.

Each measurement was performed by a single blinded rater. Prior to study initiation a sample of ten (10) images were measured. After two weeks the same images were re-measured to calculate reliability of the measurement method. Measurement parameters and their description can be found in Table 1.

\begin{table}[h]
\centering
\caption{Parameters to be measured}
\begin{tabular}{|l|l|}
\hline
Parameter & Description \tabularnewline
\hline
Intercanine width & Distance from the incisal tip of the cusp of a maxillary canine to the contralateral. \tabularnewline
\hline
Intermolar width & Distance from the mesioligual cusp of a maxillary first molar to the same point on the contralateral molar \tabularnewline
\hline
Arch length & Perpendicular distance from a point between the central incisors to a line connecting the mesial contacts of the first permanent molars. \tabularnewline
\hline
\end{tabular}
\end{table}
### Table 1 continued

<table>
<thead>
<tr>
<th><strong>Arch perimeter</strong></th>
<th>Distance from the mesial contact of one first permanent molar to its antimere as measured through the contact points, buccal cusp tips, and incisal edges of all of the intervening teeth, ignoring those teeth that are malpositioned or blocked out so that the measurement represents an ideal arch form.</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Upper airway volume</strong></td>
<td>The space occupied by air in the oral cavity, nasal passages and area behind the tongue superior to the epiglottis. For this study we will only be looking at the oropharyngeal volume. The superior limit is a line from the posterior nasal spine (PNS) to the most superior aspect of the odontoid process of the axis (C2), as done in the study by Glupker et al\textsuperscript{18}. The inferior limit is the most superior aspect of the epiglottis which is the anatomical boundary of the oropharynx.</td>
</tr>
<tr>
<td><strong>Minimum cross sectional area</strong></td>
<td>The most constricted portion of the airway as measured in square millimeters parallel with the axial plane.</td>
</tr>
</tbody>
</table>

Airway volume and minimum axial area were calculated using the sinus/airway tool in the Imaging software\textsuperscript{17}. The boundaries for oropharyngeal volume are consistent with those used in a study by Glupker et al\textsuperscript{18}. The superior boundary is defined by a line connecting the posterior nasal spine (PNS) anteriorly and the most superior aspect of the odontoid process of the axis (C2) posteriorly. The inferior limit of the oropharyngeal volume is a line at the tip of the epiglottis extending anteriorly and posteriorly parallel with the horizontal axis. A threshold method was used to segment the airway. The airway sensitivity tool was adjusted to eliminate imaging artifacts and ranged from 50-75.
Airway volume was calculated in cubic millimeters and the minimum axial area in square millimeters.

Isolation of the 3-dimensional maxillary arch was done by using the software ‘Clipping Slice’ tool to remove all structures below the occlusal plane. The software ‘Digitize/Measure’ tool with the 2D line tab selected was used to measure the maxillary arch parameters. The intercanine width was measured from the cusp tip of one maxillary canine to its contralateral. Mesiolingual cusp tip of the maxillary first molar was used for intermolar width. The arch length was found by first drawing a line connecting the mesial contact points of the maxillary first molars. The midline point of this line was connected to a point on the same plane at the most facial portion of the maxillary incisor. Arch perimeter was found by measuring from the mesial contact point of the first molar to its antimere as measured through the contact points of posterior teeth and incisal edges of anterior teeth ignoring those teeth that were malpositioned or blocked out so that the measurement represents an ideal arch form.

RESULTS

Twenty one (21) of the estimated forty (40) CBCT acquisitions had been completed at the time of analysis. Five of the subjects did not meet initial inclusion criteria and thus the
final number of subjects in the OSA group was sixteen (16). Thirty seven (37) control subjects met initial inclusion criteria. Of these sixteen were randomly selected to best match the OSA group for age. The OSA group had an average age of 41.3 (±6.9) years, as compared to 31.8 (±11.3) years in the Control group. This age difference was found to be significantly different (p=0.0097).

Intraclass correlation coefficients (Table 2) showed high reliability for all measurements (r= 0.8-1.0). Descriptive statistics for both the OSA and Control groups are represented in Table 3. The control group had a larger airway volume (16052.5 ± 6067.8 mm$^3$) than the OSA group (11588.1 ± 6894.5 mm$^3$) but this difference was not statistically significant (Table 4). There were no significant differences between the groups in intercanine width, arch perimeter or depth (p=0.7377, 0.3331, 0.7378 respectively). Each of these parameters were slightly larger in the OSA group. Intermolar width was significantly different with a raw p value (p=0.0235) but not significant when adjusting for multiple comparisons (p=0.1176).

### Table 2 Reliability of Each Measurement Parameter

<table>
<thead>
<tr>
<th>VARIABLE</th>
<th>N (per trial)</th>
<th>ICC</th>
<th>LOWER 95% BOUND</th>
<th>UPPER 95% BOUND</th>
</tr>
</thead>
<tbody>
<tr>
<td>VOLMM3</td>
<td>10</td>
<td>1</td>
<td>N/A</td>
<td>N/A</td>
</tr>
<tr>
<td>XSECAREA</td>
<td>10</td>
<td>1</td>
<td>N/A</td>
<td>N/A</td>
</tr>
<tr>
<td>IMW</td>
<td>10</td>
<td>0.97</td>
<td>0.90</td>
<td>0.99</td>
</tr>
<tr>
<td>ICW</td>
<td>10</td>
<td>0.97</td>
<td>0.90</td>
<td>0.99</td>
</tr>
<tr>
<td>ARCHPRM</td>
<td>10</td>
<td>0.97</td>
<td>0.90</td>
<td>0.99</td>
</tr>
<tr>
<td>DEPTH</td>
<td>10</td>
<td>0.99</td>
<td>0.96</td>
<td>1.00</td>
</tr>
</tbody>
</table>
### Table 3 Descriptive statistics for control and OSA group

<table>
<thead>
<tr>
<th>Group</th>
<th>N</th>
<th>Variable</th>
<th>Mean</th>
<th>Std Dev</th>
<th>Median</th>
<th>Quartile Range</th>
<th>Minimum</th>
<th>Maximum</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control</td>
<td>16</td>
<td>AGE</td>
<td>31.81</td>
<td>6.95</td>
<td>29.75</td>
<td>8.79</td>
<td>23.92</td>
<td>47.83</td>
</tr>
<tr>
<td></td>
<td></td>
<td>AWV</td>
<td>16052.50</td>
<td>6067.80</td>
<td>16044.50</td>
<td>7893.50</td>
<td>8326.00</td>
<td>30177.00</td>
</tr>
<tr>
<td></td>
<td></td>
<td>XSECAREA</td>
<td>177.44</td>
<td>77.42</td>
<td>175.50</td>
<td>130.50</td>
<td>57.00</td>
<td>290.00</td>
</tr>
<tr>
<td></td>
<td></td>
<td>IMW</td>
<td>40.41</td>
<td>3.24</td>
<td>40.80</td>
<td>5.85</td>
<td>34.80</td>
<td>44.10</td>
</tr>
<tr>
<td></td>
<td></td>
<td>ICW</td>
<td>36.13</td>
<td>3.27</td>
<td>37.00</td>
<td>4.25</td>
<td>28.00</td>
<td>40.00</td>
</tr>
<tr>
<td></td>
<td></td>
<td>PERIM</td>
<td>83.50</td>
<td>5.28</td>
<td>85.60</td>
<td>8.80</td>
<td>71.60</td>
<td>88.80</td>
</tr>
<tr>
<td></td>
<td></td>
<td>DEPTH</td>
<td>30.57</td>
<td>2.40</td>
<td>31.00</td>
<td>4.45</td>
<td>25.70</td>
<td>34.10</td>
</tr>
<tr>
<td>OSA</td>
<td>16</td>
<td>AGE</td>
<td>41.34</td>
<td>11.30</td>
<td>41.92</td>
<td>13.46</td>
<td>22.00</td>
<td>63.58</td>
</tr>
<tr>
<td></td>
<td></td>
<td>AWV</td>
<td>11588.13</td>
<td>6894.45</td>
<td>9544.00</td>
<td>5200.50</td>
<td>5543.00</td>
<td>30954.00</td>
</tr>
<tr>
<td></td>
<td></td>
<td>XSECAREA</td>
<td>73.44</td>
<td>37.07</td>
<td>70.00</td>
<td>35.00</td>
<td>1.00</td>
<td>170.00</td>
</tr>
<tr>
<td></td>
<td></td>
<td>IMW</td>
<td>42.98</td>
<td>2.67</td>
<td>42.40</td>
<td>4.15</td>
<td>38.90</td>
<td>47.60</td>
</tr>
<tr>
<td></td>
<td></td>
<td>ICW</td>
<td>37.13</td>
<td>3.08</td>
<td>37.80</td>
<td>2.90</td>
<td>28.10</td>
<td>39.90</td>
</tr>
<tr>
<td></td>
<td></td>
<td>PERIM</td>
<td>86.43</td>
<td>4.82</td>
<td>87.05</td>
<td>6.75</td>
<td>79.50</td>
<td>97.90</td>
</tr>
<tr>
<td></td>
<td></td>
<td>DEPTH</td>
<td>31.16</td>
<td>2.75</td>
<td>31.35</td>
<td>3.75</td>
<td>27.00</td>
<td>37.80</td>
</tr>
</tbody>
</table>

* AWV indicate airway volume (mm³); XSECAREA, minimum cross sectional area (mm²); IMW, intermolar width (mm); ICW, intercanine width (mm); PERIM, arch perimeter (mm); DEPTH, arch depth (mm)

### Table 4 P values

<table>
<thead>
<tr>
<th>Variable</th>
<th>Raw P Value</th>
<th>Adjusted P Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>AWV</td>
<td>0.06252</td>
<td>0.25007</td>
</tr>
<tr>
<td>XSECAREA</td>
<td>0.00022 *</td>
<td>0.00135 *</td>
</tr>
<tr>
<td>IMW</td>
<td>0.02352 *</td>
<td>0.11758</td>
</tr>
<tr>
<td>ICW</td>
<td>0.36889</td>
<td>0.73777</td>
</tr>
<tr>
<td>PERIM</td>
<td>0.11102</td>
<td>0.33305</td>
</tr>
<tr>
<td>DEPTH</td>
<td>0.51183</td>
<td>0.73777</td>
</tr>
</tbody>
</table>

* p <0.05
Minimum cross sectional area was the only parameter statistically different between groups. The Control group mean minimum cross sectional area (177.4 ± 77.4 mm²) was significantly larger (p=0.00022) than the OSA group (73.4 ± 73.1 mm²). This difference remained statistically significant after accounting for multiple comparisons (p=0.00135).

Airway volume, intermolar width and minimum cross sectional area were examined further using logistic procedures and Receiver Operating Characteristic (ROC) curves developed to assess predictive value for each parameter (Figure1-4). Airway volume had an area under curve (AUC) value of 0.7617 indicating it is a fair predictor for OSA. Intermolar width AUC was 0.7051 indicating a poor to fair predictor. Minimum cross sectional area is a good to excellent predictor of OSA (AUC= 0.8867).
Figure 1 Receiver operating characteristic curve for airway volume

ROC Curve for AWV
Area Under the Curve = 0.7617

Sensitivity

1 - Specificity

Points labeled by predicted probability
Figure 2 Receiver operating characteristic curve for intermolar width
Figure 3 Receiver operating characteristic curve for minimum cross sectional area
With minimum cross sectional area being a good to excellent predictor a cut point determination was completed. A cut point of 111 mm² was found. Based on our model the positive predictive value is calculated to be 0.842, negative predictive value of 0.941 and an accuracy of 0.889. Therefore, if a subject’s minimum cross sectional area is found
to be below the cutpoint there is an 84.2% chance they truly have OSA. If the minimum cross sectional area is measured to be above the cutpoint there is a 94.1% chance they truly do not have OSA.

DISCUSSION

The current study compared several dental and oral parameters from CBCT images that describe the size of the oral cavity and oropharyngeal airway in a group of African American males with a diagnosis of OSA with a healthy control group. To the best of the authors’ knowledge this is the first study to compare an African American OSA group to a control group. In addition, no study has compared maxillary arch parameters and airway with CBCT between an OSA and a control group. Previous studies evaluating extraction or expansion and airway size have been completed on non OSA subjects ¹¹,¹²,¹³,¹⁴,¹⁵,¹⁹,²⁰.

In the present study there was no difference between groups in maxillary intermolar width, intercanine width, arch depth, arch perimeter or oropharyngeal airway volume. These findings contradict those of Seto et al ⁴ who found significant differences in ICW, IMW or maxillary arch depth. The OSA group had smaller dimensions in all 3 parameters. These findings also contradict those by Wang ¹³ and Germec-Cakan ¹⁴ who
found post tooth extraction and orthodontic therapy decreasing arch depth led to decreased pharyngeal volume. However, these authors did not investigate whether this decrease led to a higher AHI or increased prevalence of OSA. The results of this study are that arch depth is not different between an OSA and a control group. Valiathana11 and Pliska12 found no changes in oropharyngeal volume with orthodontic extraction treatment. These results are consistent with the results of the present study conducted with non-growing adults.

Minimum cross sectional area was significantly different between the two groups. This result is consistent with the findings by Ogawa et al21 who investigated cross-section airway in subjects with OSA. Ogawa et al also reported that the minimum cross sectional area was significantly smaller in the OSA group (OSA: 45.8±17.5 mm²; non-OSA: 146.9 ± 111.7 mm² [P = .011]). Our findings are also supported by Shigeta et al who found that the Airway area/Square area (AWA/SA) at the level of the inferior border of the C2 vertebra was 8.8% smaller in OSA patients as compared to non-apneotic controls 22. The minimum cross sectional area had good-excellent predictive value. A cutpoint determination was found at 111 mm². This number can provide practitioners taking CBCTs an initial OSA screening point of reference in adult African Americans. Another cutpoint for minimum cross sectional area could not be found in the current literature. Further studies are required to determine if minimum airway cross-section is a useful screening tool when reviewing CBCT images.
One limitation was the small sample size in this study. Routine CBCT scans are not the standard of care and thus having a sample from an OSA population is difficult to obtain. Only two other studies have compared an OSA to control group with CBCT analysis \(^{21,22}\). These studies had an N of 20 and 29 respectively (10 OSA, 10 non-OSA\(^{21}\); 15 OSA, 14 non-OSA\(^{22}\)) which is comparable to the present study. Future studies with larger sample sizes are needed.

The OSA group had a mean age that is 10 years older than the controls (41.3 ±6.9 years, as compared to 31.8 ±11.3 years) and is statistically significant (p=0.0097). It is known that the prevalence of OSA increases with age\(^{23}\). This increase is hypothesized to be due to an increase in BMI and decrease in muscle tone with age. Duran et al. reported that the prevalence of OSA increases with an odds ratio (OR) of 2.2 for every 10 year increase in age for men and women\(^{24}\). Several studies have investigated the prevalence of OSA with age. Young et al. presented age specific estimates of sleep disordered breathing in the general population. From age 30-39 they estimate that 17% of males would have an AHI ≥ 5. For this same age group Duran found 9%. The 40-49 age group percentage of males was 25 and 25.6 respectively. For an AHI ≥10 the 30-39 age group was 12% vs 18% in the 40-49 age group\(^{25}\). Duran reported 7.6 vs 18.2% respectively. This data shows a greater percentage of males in the 5th decade of life have OSA than do those in the 4th decade. Our control sample was not tested by a sleep study but this data suggests they are less likely to be affected.
CBCT is a reliable tool for assessing airway and dental parameters. Maxillary dental and oral parameters were not associated with a higher risk of OSA in African American males. A decreased minimum cross-sectional area was associated with OSA in African American males and has a potential as a screening tool when a CBCT image is available. Due to small sample size this data needs to be corroborated by larger studies.

**CONCLUSIONS**

1. CBCT is a reliable tool for assessing airway and dental arch parameters.
2. African American adult males with OSA have no difference with controls in arch width, depth, or perimeter.
3. Minimum cross sectional area appears to be a useful screening tool for OSA.
4. According to the present study a cutpoint of 111 mm² is a good-to-excellent predictor with high positive and negative predictive value for OSA.
5. Due to small sample size and insufficient controls this data needs to be corroborated by larger studies.
ACKNOWLEDGMENTS

We would like to thank Cameron Anderson, Julene Mnayarji, and Eun Sang Moon for their assistance in method development, data collection and analysis. We are grateful for The Ohio State University College of Dentistry Radiology department for their support in acquiring CBCTs. We would also like to recognize the Delta Dental Foundation for their financial support.
REFERENCES


26. Epstein LJ; Kristo D; Strollo PJ; Friedman N; Malhotra A; Patil SP; Ramar K; Rogers R; Schwab RJ; Weaver EM; Weinstein MD. Clinical guideline for the evaluation, management and long-term care of obstructive sleep apnea in adults. J Clin Sleep Med 2009;5(3):263–276.
CHAPTER 4

CONCLUSIONS

1. CBCT is a reliable tool for assessing airway and dental arch parameters.

2. African American adult males with OSA have no difference with controls in arch width, depth, or perimeter.

3. Minimum cross sectional area appears to be a useful screening tool for OSA.

4. According to the present study a cutpoint of 111 mm$^2$ is a good-to-excellent predictor with high positive and negative predictive value for OSA.

5. Due to small sample size and insufficient controls this data needs to be corroborated by larger studies.


26. Epstein LJ; Kristo D; Strollo PJ; Friedman N; Malhotra A; Patil SP; Ramar K; Rogers R; Schwab RJ; Weaver EM; Weinstein MD. Clinical guideline for the evaluation, management and long-term care of obstructive sleep apnea in adults. J Clin Sleep Med 2009;5(3):263–276.