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Friedman Tongue Position and Cone Beam Computed Tomography in Patients with Obstructive Sleep Apnea

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Objective: Evaluate the correlation between Friedman Tongue Position (FTP) and airway cephalometrics in patients with obstructive sleep apnea (OSA).

Study Design: Retrospective review of adult patients with OSA undergoing Cone Beam Computed Tomography (CBCT).

Methods: Collected data included age, sex, body mass index, apnea hypopnea index, FTP, and airway cephalometric parameters. Data analyses were performed using ANOVA, dichotomous t-testing, and linear regression.

Results: 203 patients were included in the analysis. (M:F 132:71). The mean posterior airway space (PAS) was inversely correlated ($p = 0.001$, r =.119) with higher FTP grades with means of 12.3 mm, 7.9 mm, 6.6 mm, and 4.3 mm, I-IV respectively. Minimal cross-sectional area for patients with FTP I-IV was 245.7, 179.8, 137.6, and 74.2 mm, 2 respectively ($p = 0.002$, $r = .095$). Mean hyoid-mandibular plane (H-MP) for FTP I-IV was 20.6 mm, 20.4 mm, 24.7 mm, and 28.9 mm respectively. No statistically significant difference between H-MP values when comparing patients with FTP I or II ($p = 0.22$). There were statistically significant differences when these two groups were individually compared to FTP III and IV ($p = 0.002$). Linear regression analysis confirmed an independent association between FTP and PAS ($\beta = -2.06$, $p < 0.001$), minimal cross-sectional area ($\beta = -45.07$, $p = 0.02$), and H-MP ($\beta = 3.03$, $p = 0.01$) controlling for BMI, age, AHI, and sex.

Conclusions: Use of FTP is supported by objective CBCT cephalometric results, in particular the PAS, minimal cross-sectional area, and H-MP. Understanding the correlation between objective measurements of retroglossal collapse should allow Otolaryngologists to more confidently select patients who may require surgery to address the retroglossal area, particularly when the ability to perform cephalometric analysis is not possible

Key Words: Obstructive sleep apnea, surgical treatment of obstructive sleep apnea, sleep apnea.

Level of Evidence: 4.

INTRODUCTION

Obstructive sleep apnea (OSA) is defined by the American Academy of Sleep Medicine as recurrent collapse of the upper airway during sleep, resulting in total (apnea) or partial (hypopnea) reduction in airflow.[1] Changes in the mechanical physiology of respiration during sleep, including marked relaxation of upper airway muscles, result in doubling of the total upper airway resistance compared to wakefulness.[2] The upper airway includes the portion of the respiratory system between the nares and proximal trachea. Multiple sites of potential obstruction exist within the upper airway including the retropalatal and retroglossal areas.

The Friedman Tongue Position (FTP) is a grading system used to assess the relationship of the palate to the tongue and is frequently utilized in the preoperative evaluation of patients with OSA. The tongue is evaluated in a neutral position within the oral cavity. The procedure for assigning an FTP grade involves having a patient open their mouth widely without tongue protrusion or phonation. Higher FTP grades predict a significantly lower likelihood of improvement following uvulopalatopharyngoplasty (UP3).[3,4] Cone Beam Computed Tomography (CBCT) has emerged as an additional tool to assess upper airway dimensions and aid in the surgical evaluation of patients with OSA. CBCT data include a variety of objective airway measurements that help identify potential sites of obstruction in patients with OSA.

Few studies have investigated the relationship of Friedman Tongue Position and cephalometric data obtained from CBCT.[5] Previous studies have shown that a posterior airway space (PAS) <8 mm is predictive of tongue base collapse but these studies did not directly correlate PAS with FTP.[6,7] A large retrospective series published by Riley et al. demonstrated that patients

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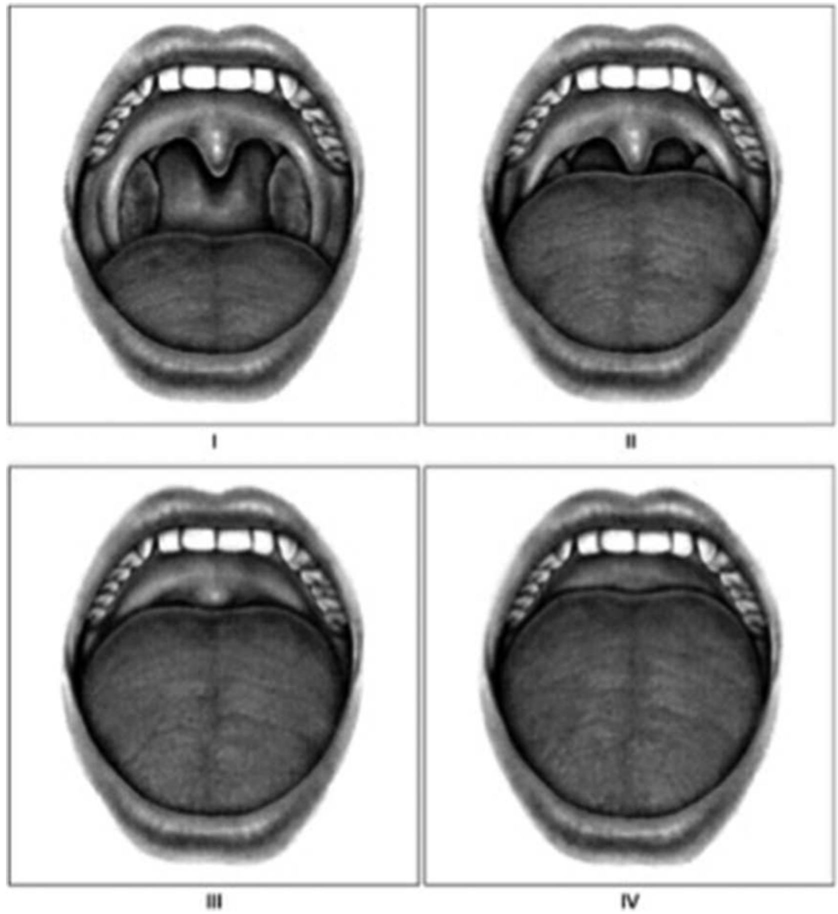

Fig. 1. Friedman Tongue Position Grade. Grade I allows the observer to visualize the entire uvula and tonsils. Grade II allows visualization of the uvula bot not the tonsils. Grade III allows visualization of the soft palate but not the uvula. Grade IV allows visualization of the hard palate only.

with a posterior airway space of less than 8 mm are less likely to respond to isolated palatal surgery and may require additional surgery directed at the tongue base.[7] Other cephalometric data points, such as sella-nasion-A point (SNA) and sella-nasion-B point (SNB) angles, are frequently used by oral maxillofacial surgeons when planning orthognathic surgery in order to determine the direction and extent of maxillomandibular advancement.[8] The objective of this study was to evaluate the relationship between FTP and CBCT airway measurements in patients with OSA.

METHODS

This study was approved by the University of Michigan Institutional Review Board (HUM 00108847) and was a retrospective review of adult patients attending an "Alternatives to CPAP Clinic" from September 2009 to December 2015. This multidisciplinary clinic is designed to evaluate patients who have failed to tolerate continuous positive airway pressure (CPAP) therapy for possible alternative treatments, including surgical intervention. All patients were evaluated independently by an otolaryngologist, oral maxillofacial surgeon, an American Board of Dental Sleep Medicine certified dentist, and a sleep medicine physician on the same day. Physical examination including assessment of FTP was completed by an otolaryngologist. Cone-beam computed tomography with cephalometric analysis was performed by an oral maxillofacial surgeon. Following review of the above findings, previous polysomnography results and completion of a dental evaluation, each patient was then discussed in a collaborative fashion and individualized treatment recommendations were generated.

Demographic data collected included age, sex, body mass index (BMI), apnea hypopnea index (AHI), and Friedman tongue position (Fig. 1). FTP I allows the observer to visualize the entire uvula, tonsils, and tonsillar pillars. FTP II allows only partial visualization of the uvula, tonsils, and pillars. FTP III allows the observer to visualize most of the soft palate. FTP IV allows the observer to visualize the hard palate only.

All CBCT scans were obtained at the University of Michigan by the same radiological technician using the EWOO Master 3DS (EWOO Technology USA Inc., Houston, TX) with the following settings: 90.0 kV, 3.3 mA, 20 cm x 19 cm field of view, 15-s exposure time, normal quality mode, 0.2 mm thickness of slices, and isotropic voxel with a size of 0.40 mm. Lateral cephalograms and CBCT DICOM files were imported into the Dolphin imaging software (Dolphin Imaging version 11.8.06.24 Premium) for 2- and 3-dimensional airway analysis. Two-dimensional measurements derived from CBCT scan were measured with the mid-sagittal plane set at nasion. Cephalometric measurements obtained included posterior airway space (PAS), the linear measurement between the base of the tongue and the posterior pharyngeal wall, sella-nasion-infraspinale (SNA), the angle formed by the union of the S point, the midpoint of the sella turcica, with point N, which corresponds to the junction frontal and nasal bones, and point A, the most concave point on the anterior surface of the maxilla; sella-nasion-supramentale (SNB), the angle formed by the union of the S point with the N point and B point, the most concave point of the anterior

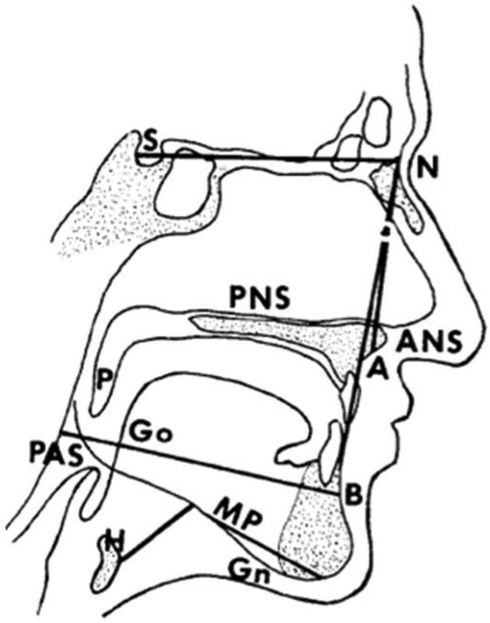

Fig. 2. Diagram of Cephalometric Tracing and Analysis

surface of the mandible; hyoid to mandibular plane (H-MP), the perpendicular distance between the mandibular plane and the hyoid bone, and soft palate length; the distance of the posterior nasal spine to the tip of the uvula (PNS-P) (Fig. 2). Normative values for these measurements are listed in Table I. To obtain the minimal cross-sectional area, the 3-dimensional airway analysis module in Dolphin Imaging was utilized.

Data analysis was performed using univariate analysis of variance (ANOVA) in which patients were first analyzed according to the Friedman tongue position grade. Next, dichotomous variable t-tests were performed by grouping patients into Group A (Friedman I/II) and Group B (Friedman III/IV) scores. Dichotomous grouping was performed due to the smaller percentage of patients with obstructive sleep apnea who presented with FTP I and II. These analyses were followed by a linear regression analysis using apnea hypopnea index (AHI), age, sex, and BMI as independent variables.

RESULTS

Data from 480 patients attending an "Alternatives to CPAP Clinic" were reviewed. A total of 203 patients undergoing evaluation had all necessary data points documented: including Friedman tongue position grade, results of cephalometric analysis assessed by CBCT, demographic data (including age, sex, and BMI), and polysomnography (PSG) results with documented AHI. Of the 203 patients included in the study, 132 (65%) were male and 71 (35%) were female. The mean age was 51.3 years, with a range of 17.3 to 83.3 years. The mean BMI was 30.9 kg/m^2 with a range from 19.4 to 51.0 kg/m^2. The mean Apnea-Hypopnea Index obtained from prior polysomnography was 32.4 event/hour with a range from 5.8 events/hour to 110.3 events/hour (Table II).

TABLE I.
Normative Cephalometric Values.[15]

Cephalometric Measures	Normal values
SNA	82° ± 3°
SNB	79° ± 3°
H-MP	15 mm ± 3 mm
PAS	11 mm ± 1 mm
PNS-P	37 mm ± 3 mm

Source: Peterson's Principles of Oral and Maxillofacial Surgery.
SNA = sella-nasion-infraspinale; SNB = sella-nasion-supramentale; H-MP = hyoid-mandibular plane; PAS = posterior airway space; PNS-P = length of soft palate.

TABLE II.
Demographics.

	Minimum	Maximum	Mean	SD
Age, yr	17.3	83.3	51.3	13.0
Body mass index, kg/m^2	19.4	51.0	30.9	5.7
Apnea hyponea index events/hour	5.8	110.3	32.4	26.0

ANOVA was performed comparing each FTP grade to airway cephalometric data points (Table III). The mean posterior airway space area was inversely correlated ($p = 0.001$, $r = 0.119$) with higher Friedman tongue position grades. The mean PAS for patients with FTP I-IV was 12.3 mm, 7.9 mm, 6.6 mm, and 4.3 mm, respectively. When the site of maximal obstruction was the retroglossal area, the minimal cross-sectional area for patients with FTP I-IV was 245.7, 179.8, 137.6, and 74.0 mm^2 respectively. Minimal cross-sectional area were inversely correlated with a higher Friedman tongue position grades ($p = 0.002$, $r = 0.095$). The average H-MP for FTP I-IV was 20.6 mm, 20.4 mm, 24.7 mm, and 28.9 mm, respectively. There was no statistically significant difference between the H-MP values when comparing patients with Friedman Tongue Position I or II ($p = 0.22$). However, there were statistically significant differences when these two groups were individually compared to FTP III and IV. In addition, a statistically significant difference was found between FTP III and IV ($p = 0.002$). There were no statistically significant correlations identified between FTP and SNA, SNB, or PNS-P.

Previous studies have shown that the majority of patients with obstructive sleep apnea present with either FTP II or III.[9] Therefore, to further facilitate data analysis, patients included in the study were divided into two groups according to FTP stage and t-tests were performed. Group A included patients with FTP I or II and Group B was composed of patients with FTP III or IV. A statistically significant difference ($p = 0.01$) was observed between Group A and Group B patients for PAS, minimal cross-sectional area, and H-MP measurements (Table IV).

Previous studies have shown that FTP is positively correlated with both BMI and AHI independent of each other.[10,11] Therefore, separate linear regression analyses were performed to evaluate the association of FTP with airway cephalometric parameters independent of other possible confounding variables. These analyses

TABLE III.
Descriptive Statistics for FTP.

FTP Stage	Frequency	%	SNA degrees Mean	SNA degrees SD	SNB degrees Mean	SNB degrees SD	H-MP mm Mean	H-MP mm SD	PNS-P mm Mean	PNS-P mm SD	PAS mm Mean	PAS mm SD	Minimal Airway Area mm^2 Mean	Minimal Airway Area mm^2 SD
I	5	3	80.9	1.9	78.2	2.2	20.6	6.3	30.3	1.9	12.3	2.8	245.7	75.9
II	27	13	83.5	3.8	81.1	3.5	20.4	8.8	39.7	7.3	7.9	3.4	179.9	124.7
III	157	77	83.0	4.9	80.2	4.3	24.7	7.4	38.8	8.2	6.2	3.2	137.6	110.5
IV	14	7	85.0	4.6	81.9	5.3	28.9	9.0	37.6	8.6	4.3	1.5	74.0	48.5

confirmed that there is an independent association between FTP and PAS ($\beta = -2.06$, $p < 0.001$), minimal cross-sectional area ($\beta = -45.07$, $p = 0.02$), and H-MP ($\beta = 3.03$, $p = 0.01$) after controlling for BMI, age, AHI, and sex.

DISCUSSION

Obstructive sleep apnea is a common sleep disorder characterized by repeated collapse of the upper airway during sleep. Obstruction may occur at the retropalatal area, retroglossal area, or both. The genioglossus muscle is the principal upper airway dilator. It originates from the hyoid bone and inserts on the genial tubercle of the mandible along its lingual surface. The more posterior the bony origin and insertion points, represented by H-MP and SNB measurements, the further posterior the expected position of the genioglossus muscle and hence, the tongue. Due to loss of muscle tone during sleep, a more posterior location of the genioglossus muscle would be expected to be associated with an increased propensity for retroglossal obstruction. Of the cephalometric variables assessed in this study, the posterior airway space (PAS) and minimal retroglossal cross-sectional area are direct measures of the actual space between the tongue base and posterior pharyngeal wall. Thus, these measures would be expected to most accurately predict a retroglossal site of obstruction. This study demonstrated a statistically significant inverse relationship between the FTP and PAS as well as the minimal retroglossal cross-sectional area. In addition, a statistically significant positive correlation between FTP and H-MP was found providing compelling evidence to further support the use of FTP to predict a retroglossal site of collapse.

The SNA and SNB are measurements of the angles between the sella, nasion, and the maxilla or mandible, respectively. If the SNA or SNB is greater or less than normal, this indicates that the mandible or maxilla is either positioned too far anteriorly or posteriorly. SNA and the SNB are considered abnormal when they are two degrees above or below the norm implying prognathism and retrognathism, respectively. In our study, no statistically significant correlation was found between FTP and SNB. However, this may not be unexpected as previous studies have demonstrated that there does not appear to be a direct correlation between SNB and PAS.[12] SNB provides useful information about the position of the mandible but does not provide a direct measurement of the retroglossal airway. Some patients may have a slightly retrognathic mandible and smaller tongue without significant retroglossal obstruction. Conversely, some patients may be slightly prognathic or have normal mandibular anatomy yet still have an abnormally small retroglossal area due to the presence of a large muscular tongue or marked lingual tonsillar

TABLE IV.
Comparison Between Group A and Group B Classification.

		N	Mean	Std. Deviation	*p* value
SNA	Group A	32	83.1	3.8	0.91
(degrees)	Group B	171	83.2	4.9	
SNB	Group A	32	80.7	3.5	0.83
(degrees)	Group B	171	80.4	4.4	
H-MP	Group A	32	20.4	5.2	0.001
(mm)	Group B	165	25.0	7.7	
PNS P	Group A	31	38.4	7.7	0.86
(mm)	Group B	164	38.7	8.2	
PAS	Group A	27	8.6	3.7	0.002
(mm)	Group B	148	6.1	3.1	
Minimal Airway Area mm^2	Group A	32	190.2	122.7	0.007
	Group B	167	132.3	108.5	

Group A = FTP I/II.
Group B = FTP III/IV.

hypertrophy. In addition, no significant relationship between FTP and SNA or PNS-P was identified. This would be expected as these two values are more likely to be associated with a retropalatal site of obstruction and not a retroglossal site of collapse.

The Friedman tongue position was devised to help identify patients with a high likelihood of retroglossal collapse. Many studies have investigated how FTP can be used as a validated predictor for success of UP3 surgery. In addition, FTP has also been used to help guide surgical decision making.[3,4,10,11] Previous studies have demonstrated a significant correlation between the FTP and pharyngeal manometry results in patients with retroglossal obstruction.[13] Drug induced sleep endoscopy findings have also been correlated with the Friedman Stage of patients undergoing evaluation for sleep surgery.[14] In addition, FTP has also been found to correlate strongly with OSA severity.[3] However, limitations of the FTP grading system include that it does not directly measure the length of the soft palate, but rather assesses the relationship of the palate to the tongue. It also does not address inter-pillar or inter-tonsillar distance, which may be important considerations when determining surgical candidacy. In addition, this system does not assess for the presence of lingual tonsillar hypertrophy or palatine tonsillar hypertrophy, although the latter is included in the more encompassing Friedman staging system. Another limitation of the FTP grading system is that the majority of adult patients with OSA are either FTP grade II or III, consistent with the findings of the current study.[9]

Cephalometric analysis and CBCT have emerged as tools to objectively evaluate potential sites of obstruction in patients with OSA. This additional information may help identify appropriate surgical candidates for tongue base procedures and predict surgical outcomes. However, most otolaryngologists do not routinely have access to cephalometric analysis when evaluating patients with OSA unless patients are seen in the context of a multidisciplinary sleep clinic or separately by an oral maxillofacial surgeon. The majority of otolaryngologists evaluating candidates for sleep surgery have to rely on the integration of polysomnography results and physical exam findings including the FTP. To our knowledge, this is the first study to investigate the relationship between FTP and cephalometric measurements in an effort to further understand the clinical utility of FTP in guiding surgical decision making.

Limitations of this study include its retrospective nature. In addition, not all patient charts reviewed had documentation of all data points of interest. Furthermore, patients who did meet inclusion criteria were selected from a unique population of patients with OSA who were intolerant of CPAP therapy and highly motivated to seek alternative surgical treatments. Therefore, the findings of this study may not be completely generalized to a broader population of patients with OSA. On the other hand, surgical evaluation and intervention is not typically recommended for those patients with OSA who are CPAP compliant. Further investigation is needed to assess the findings of this study on surgical outcomes.

In conclusion, the use of the Friedman tongue position in predicting a retroglossal site of obstruction in patients with OSA is largely supported by objective CBCT cephalometric findings. The significant correlation between FTP and objective measures of retroglossal obstruction including PAS, minimal retroglossal cross-sectional area and H-MP distance demonstrated in this study should provide additional confidence to otolaryngologists in identifying patients who may benefit from surgery aimed at addressing a retroglossal site of collapse.

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