BIMAXILLARY ORTHOGNATHIC SURGERY AND SLEEP DISORDERED BREATHING OUTCOMES

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ABSTRACT

Jason M. Scherer: Bimaxillary Orthognathic Surgery and Sleep Disordered Breathing Outcomes
(Under the direction of Ceib Phillips)

Introduction: Sleep disordered breathing (SDB) is a serious condition associated with increased morbidity and mortality. Studies vary on whether bimaxillary orthognathic surgery (BOS) increases the risk of SDB, and no study has assessed impact on sleep-related quality of life (QofL). The objective was to assess whether BOS patients are at an increased risk for SDB and/or a reduction in QofL compared to a control treated with orthodontics-only. **Methods:** The two groups were asked to complete three sleep questionnaires: The Berlin Questionnaire, Functional Outcomes of Sleep-10 (FOSQ-10), and Epworth Sleepiness Scale (ESS). **Results:** There was no significant difference between the BOS and orthodontic-only groups in the Berlin or FOSQ-10 questionnaires. According to the ESS, there was significantly less daytime sleepiness in the BOS group. **Conclusions:** The results suggest that BOS patients are at no greater risk for SDB and/or reduction in sleep-related QofL compared to patients treated with orthodontics alone.

ACKNOWLEDGEMENTS

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LITERATURE REVIEW

Introduction and Epidemiology of Sleep Disordered Breathing

Sleep disordered breathing (SDB) is regarded as a spectrum of diseases involving increased upper airway resistance during sleep and includes snoring, upper airway resistance syndrome, and obstructive sleep apnea (OSA).[1] Individuals with SDB can progress, in severity, from snoring to OSA with increased airway collapse over time. OSA is the most severe form of SDB and is characterized by the recurrent narrowing and obstruction of the pharyngeal airway during sleep. OSA and other forms of SDB have been reported to increase the risk of morbidity and mortality through their association with diabetes, hypertension, cardiovascular disease, and cerebrovascular disease.[2-7] It is thought that 93% of women and 82% of men with moderate to severe OSA remain undiagnosed.[8] The gold standard for diagnosing SDB, including OSA, is overnight polysomnography (PSG).[9] Through recording physiological and breathing functions during sleep, PSG measurements are used identify and classify the severity of SDB.

OSA is classified in terms of apneas and hypopneas. An apnea is defined as the cessation of breathing for at least 10 seconds, while a hypopnea is defined as a reduction in airflow and decrease in oxyhemoglobin saturation ending with an arousal from sleep.[10] The apnea-hypopnea index (AHI), which measures apneas and hypopneas per hour of sleep, is used to classify severity of OSA. Severity classifications can vary in the literature, but the most common OSA severity classifications are mild (AHI $\geq$5), moderate (AHI $\geq$15), and severe (AHI$\geq$30).[3,10]

The prevalence of OSA in the United States and abroad has been increasing since population studies were conducted. A widely cited population study by Young et al.,[11] using polysomnography data from the Wisconsin Sleep Cohort Study in the 1990's, found the prevalence of OSA in adults to be between 2% and 4%.[11] A follow-up study from 2007-2010 using the same cohort found the overall prevalence of OSA in adults to be estimated at 26%.[12] Increases in obesity are cited as a major reason for the increased prevalence of OSA.

Obesity is a common clinical finding for patients with OSA and is estimated to be found in more than 60% of patients referred for sleep studies.[13] Excess body weight is consistently recognized as the greatest risk factor for the development of OSA, and multiple longitudinal studies have shown that body mass index (BMI) increases can lead to the development of moderate to severe OSA.[14,15] Due to local fat deposition, the upper airway can become more sensitive to collapse in overweight individuals. Being overweight and obese is a strong causal factor for OSA development, and with obesity becoming a major epidemic in the United States and abroad, the prevalence of OSA will almost certainly increase accordingly.

Population studies have consistently identified men as having a greater prevalence for OSA.[8,11,12,16] Sex differences in the anatomical and functional aspects of the upper airway have been thought to attribute to the increased prevalence of OSA among males.[17] Hormonal influences also appear to have a role in OSA risk. For example, post-menopausal women were found to be at a significantly higher risk for OSA than premenopausal women and post-menopausal women on hormone replacement therapy.[16] This is consistent with the finding of a stronger relationship between increased age and SDB in women than in men.[12] Population studies have shown OSA prevalence to increase with age in both men and women.[16,18] Moreover, studies have found that more than half of adults over the age of 65 have some form of

chronic sleep-related complaint.[19] The risk of OSA with increasing age, however, may not be of significance until middle age. The popular risk assessment questionnaire, the STOP-Bang, uses age 50 as a threshold for increased OSA risk.[20]

The majority of population studies examining OSA prevalence have looked at Caucasians subjects. Recently, disease prevalence in other racial and ethnic groups has been explored. Studies have shown that OSA prevalence in Asian populations is similar to that of Western societies even though Asians are less overweight than western populations. Moreover, OSA severity has been shown to be greater in Asian populations.[21] In studies with African-American subjects, OSA prevalence in adults is comparable to that of other racial groups.[22] However, in older (≥65) and younger (≤25) age groups, the prevalence and severity of OSA among African-Americans has been found to be greater.[23] Data from the Sleep Heart Health Study indicates that snoring is more common in Hispanics than in whites.[24] Increased prevalence of OSA in non-white populations may be attributed to the higher prevalence of comorbid medical conditions, including obesity.

Craniofacial anatomy differences can also affect and individual's risk for OSA. Soft and hard tissue variations can alter the upper airway and increase the risk of its collapse during sleep. Anatomical structures that have been found to increase the risk of OSA are tonsillar hypertrophy, enlarged tongue or soft palate, maxillary and mandibular retrusion, inferiorly positioned hyoid bone, and a reduction in posterior airway space.[25] A review of the literature noted that mandibular body length demonstrated a significant association with OSA.[26] Detectable craniofacial abnormalities are clinically important in identifying patients that could be considered high risk for OSA. Moreover, jaw surgeries that alter the soft and hard tissues of the craniofacial complex should be carefully evaluated for their impact on OSA risk.

Bimaxillary Surgery and Airway

Mandibular setback surgery, either alone or in conjunction with maxillary advancement, is a surgical treatment option for patients with skeletal class III malocclusions. This type of malocclusion is characterized by either mandibular prognathism, maxillary deficiency, or a combination of both. Several studies have suggested that patients may develop OSA after mandibular setback surgery due to a narrowing of the posterior airway space (PAS).[27-29] In a recent systematic review of cephalometric and cone-beam computed tomography (CBCT) studies on setback surgery and airway, the authors concluded that there is moderate evidence that isolated mandibular setback surgery leads to a decrease in oropharyngeal airway volume after surgery.[30] Follow-up studies of a year or greater have also shown a continued decrease in upper and middle airway dimension over time.[31,32]

Due to concerns about airway reduction and unfavorable facial profile esthetics, many surgeons in the United States are doing fewer isolated mandibular setbacks. Less than 10% of class III surgery patients are receiving isolated setbacks, while approximately 40% undergo bimaxillary orthognathic surgery (combination of mandibular setback and maxillary advancement); the other half receive maxillary advancement surgery alone.[33] With the growing preference for bimaxillary orthognathic surgery (BOS) over isolated setbacks, many studies have looked at its effect on the airway. Changes in airway measurements after orthognathic surgery have traditionally been calculated from 2-dimensional (2D) lateral cephalograms, but recently, 3-dimesional (3D) studies using CBCT imaging are becoming the norm. A recent study by Sears et al. identified a lack of correlation between 2D and 3D airway size and volume measurements after orthognathic surgery.[34] They concluded that using a 2D lateral cephalogram for airway measurements is not a reliable substitute for 3D imaging. According to Isono et al., the axial

plane, which cannot be visualized from 2D imaging, is the most relevant plane because it is perpendicular to the airflow.[35] Even with the increase in 3D airway studies, the effect of BOS on airway volume is still not clear. Some CBCT studies found an overall decrease in airway volume after BOS,[36-39] but others found an increase,[40] or even no change.[41,42]

Although studies have reported an association between reduced airway volume and the risk for sleep disordered breathing, threshold limits for airway size have not been established for the development or severity of SDB. Moreover, airway studies are becoming less concerned about the change in total airway volume and instead focusing on the link between SDB and the narrowest cross-sectional area of the airway where the obstruction occurs.[40] The size and shape of the airway may also have an impact on the presence and severity of OSA. Abramson et al. found that the presence of OSA was associated with an increase in airway length and decreasing lateral/anteroposterior dimension ratio.[43] They suggested that small decreases in the cross-sectional airway along an increased airway length may magnify a patient's airway resistance.[43]

Bimaxillary Surgery and Sleep Apnea Risk

Even if BOS leads to a decrease in airway volume, the risk for developing OSA after surgery has not been sufficiently explored. Studies are limited, and conclusions vary regarding the extent to which BOS leads to SDB confirmed by polysomnography.[40,44,45] In the PSG study of Foltán et al,[44] BOS was found to worsen respiratory parameters with significant decreases in oxygen saturation (SpO2) and nasal airflow measured before and after (mean 8.5 months) surgery. However, in a different PSG study, Hasebe et al[45] was unable to detect significant differences in SDB or changes in SpO2 or AHI in patients 6 months after BOS. The investigators did note that 2 patients with very large mandibular setbacks were diagnosed with mild OSA after

surgery. Turnbull and Battagel[46] compared overnight pulse oximetry and respiratory noises before and after BOS and found no significant changes despite identifying a reduction in the retrolingual airway diameter in all patients. In a recent PSG study by Gokce et al.,[40] sleep quality and efficiency improved significantly after BOS (mean 1.4yrs) with significant increases in SpO_2 and decreases in AHI.

Although the diagnostic gold standard for assessing OSA is overnight polysomnography (PSG), validated questionnaires are frequently used as convenient and cost-effective screening tools for OSA.[9] The Berlin Questionnaire is a validated survey that scores subjects as "high risk" or "low risk" for OSA.[47] In a study done in a primary care setting, the Berlin was found to predict an AHI>5 with a sensitivity of 0.86, a specificity of 0.77, and a positive predictive value of 0.89.[48] In a recent systematic review of validated OSA screening questionnaires, the Berlin had a pooled sensitivity and specificity of, 0.77 and 0.74, respectively.[49] Encisco et al found that subjects having a "high risk" score on the Berlin are 5.8 times more likely to have OSA than subjects with no risk.[50] The Berlin Questionnaire is composed of 10 questions divided among 3 symptom categories: snoring, daytime sleepiness, and obesity/hypertension. Patients with frequent and persistent symptoms in any 2 of the 3 categories are considered at high risk for OSA. At least 2 affirmative answers in either the snoring or daytime sleepiness categories is confirmation of the presence of that symptom. For the obesity/hypertension category, an answer of "yes" to having hypertension or a body mass index (BMI) of $>30kg/m^2$ is considered a positive score. In a national sleep poll of 1506 people, the Berlin Questionnaire found 19% of participating adults to meet the criteria for high risk of OSA.[51]

Based on their previous work with the Berlin questionnaire, Chung et al.[20] developed the STOP and the STOP-BANG questionnaires to assess OSA risk. The STOP consists of four

yes/no questions on *S*noring, *T*iredness during the day, *O*bserving cessation of breathing during sleep, and high blood *P*ressure.[20] The STOP-Bang questionnaire is an alternative scoring model incorporating *B*MI, *a*ge, *n*eck circumference, and *g*ender. A patient is considered to be at high risk for OSA if they answer "yes" to three or more items. In a systematic review of OSA questionnaires by Abrishami et al.,[49] the STOP-Bang questionnaire had the highest sensitivity for predicting moderate and severe OSA at .0.93 and 1.0, respectively. It was also reported in the review that the STOP and STOP-Bang had the highest methodological validity and easy-to-use features.

Bimaxillary Surgery and Sleep-Related Quality of Life

A number of studies have examined quality of life subsequent to jaw surgery for dentofacial deformities,[52] however, no studies were identified that explored the impact of Class III jaw surgeries on sleep-related quality of life. While objective measures of SDB have traditionally been reported in the literature, quality of life assessments are increasingly being recognized as an important outcome variable as well.[53,54] PSG values such as AHI and SpO_2 are good objective measures of SDB risk but do not address patients' perception of quality of life.

Disease-specific quality of life questionnaires have been developed to assess how sleep disorders affect quality of life. The Functional Outcomes of Sleep Questionnaire (FOSQ-30) is a valid and reliable 30-item questionnaire that is considered to be the gold standard in assessing the impact of sleepiness on quality of life.[55] The FOSQ-10 is a shorter version of the original FOSQ-30 and has been shown to be easier to use and to reach the same statistical conclusions as the longer version regarding comparisons in sleep-related quality of life between normal controls and patients with OSA.[56] The FOSQ-10 assesses quality of life via 10 questions measuring 5

subscales: general productivity, activity level, vigilance, social outcome, and intimacy and sexual relationships.[55] Each question is scored from 1-4, with 1 indicating "yes, extreme difficulty" and 4 being "no difficulty" performing the activities in question. A score of 0 is applied to the question if the subject marks not applicable or if there is a missing response. A mean-weighted item score is computed for those subscales with more than one item, and the total score is then derived by calculating the mean of the subscale scores and multiplying that mean by five. Total scores range from 5-20 with lower values suggesting poorer sleep-related quality of life. According to the authors, a total score greater than or equal to 18 shows a normal functional status.[55]

The Pittsburgh Sleep Quality Index (PSQI) is a validated sleep questionnaire used to assess sleep quality during the previous month. It contains 19 questions that fall within 7 sleep components: duration of sleep, sleep disturbance, sleep latency, habitual sleep efficiency, use of sleep medicine, daytime dysfunction due to sleepiness, and overall sleep quality.[57] Each component yields a score from 0 to 3, with 3 indicating the worst sleep quality. The sleep component scores are summed to yield a global sleep quality score that ranges from 0 to 21 with scores greater than 5 indicating poor sleep quality during the previous month.[57]

The Epworth Sleepiness Scale (ESS) assesses daytime sleepiness and is one of the most widely used sleep assessment questionnaires in clinical settings. The scale can distinguish between patients with excessive daytime sleepiness and normal subjects.[58] Although the ESS has been found to have a low predictive value when used as a screening method for OSA,[59-61] a study using participants from the Sleep Heart Health Study found excessive daytime sleepiness to be strongly associated with reduced quality of life.[53] The subject rates from 0-3 (0-never, 3-high) his/her chances of dozing off in eight situations that are often encountered in daily life.

ESS scores range from 0-24, and a score >10 (i.e. 11+) is considered indicative of excessive daytime sleepiness.[58] In a recent study evaluating ESS scores between OSA patients and non-OSA patients, the average values found were 10.94 and 7.73, respectively.[61] Johns et al. has estimated that 10-20% of the general population has ESS scores >10.[62]

Conclusion

Sleep disordered breathing, including OSA, is a serious condition associated with increased morbidity and mortality.[2-7] Isolated mandibular setbacks are becoming rare in the United States due to both esthetic reasons and concerns over the risk of airway reduction possibly leading to SDB. Studies on the effects of BOS on sleep function are limited and lead to varying conclusions. Moreover, no study was identified that assessed patients' perception of sleep-related quality of life after BOS. With the prevalence of sleep disordered breathing (SDB) known to increase with age and evidence suggesting continual decreases in airway space after setback surgery, long-term follow up studies on BOS and SDB risk are needed.[18,31,32,63] In addition, prospective research is needed to evaluate sleep-related quality of life before and after BOS and to examine correlations between PSG data, sleep questionnaires, and 3D airway parameters. The ability to more clearly identify an orthognathic surgery patient's pre-surgical risk of developing SDB is a goal that would guide surgeons and benefit patients in the future.

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Sleep disordered breathing (SDB) is regarded as a spectrum of diseases involving increased upper airway resistance during sleep and includes snoring, upper airway resistance syndrome, and obstructive sleep apnea (OSA).[1] Individuals with SDB can progress, in severity, from snoring to OSA with increased airway collapse over time. OSA is characterized by the recurrent narrowing and obstruction of the pharyngeal airway during sleep. OSA and other forms of SDB have been reported to increase the risk of morbidity and mortality through the association with diabetes, hypertension, cardiovascular disease, and cerebrovascular disease.[2-4] With the prevalence of OSA among adults in the United States estimated at 26%,[5] jaw surgeries that could alter the risk for OSA should be carefully evaluated.

Mandibular setback surgery, either alone or in conjunction with maxillary advancement, is a surgical treatment option for patients with skeletal class III malocclusions. This type of malocclusion is characterized by either mandibular prognathism, maxillary deficiency, or a combination of both. Several studies have suggested that patients may develop OSA after mandibular setback surgery due to a narrowing of the posterior airway space (PAS).[6-8] In a recent systematic review of cephalometric and cone-beam computed tomography (CBCT) studies on setback surgery and airway, the authors concluded that there is moderate evidence that isolated mandibular setback surgery leads to a decrease in oropharyngeal airway volume after surgery.[9]

Follow-up studies of a year or greater have also shown a continued decrease in upper and middle airway dimension over time.[10,11]

Due to concerns about airway reduction and unfavorable facial profile esthetics, many surgeons in the United States are doing fewer isolated mandibular setbacks. Less than 10% of class III surgery patients are receiving isolated setbacks, while approximately 40% undergo bimaxillary orthognathic surgery (combination of mandibular setback and maxillary advancement); the other half receive maxillary advancement surgery alone.[12] With the growing preference for bimaxillary orthognathic surgery (BOS), many recent studies have looked at its effect on the airway. In recent CBCT studies on changes in airway volume after BOS, the effect on the airway is still not clear. Some CBCT studies found an overall decrease in airway volume after BOS,[13-15] but others found an increase,[16] or even no change.[17,18]

Although studies have reported an association between reduced airway volume and the risk for sleep disordered breathing,[19] threshold limits for airway size have not been established for the development of SDB. Even if BOS leads to a decrease in airway volume, the risk for developing SDB after surgery has not been sufficiently explored. Studies are limited, and conclusions vary, regarding the extent to which BOS leads to SDB confirmed by polysomnography (PSG).[16,20,21] PSG values are good objective measures of SDB risk, but they fail to address patients' perception of sleep-related quality of life. No study was identified that assessed patients' perception of sleep-related quality of life after BOS.

With the prevalence of sleep disordered breathing known to increase with age and evidence suggesting continual decreases in airway space after setback surgery, long-term follow up studies on BOS and SDB risk are needed.[10,11,22] The purpose of this study was to assess

whether patients with skeletal class III malocclusions who underwent bimaxillary orthognathic surgery are at an increased risk for OSA and/or a reduction in perceived sleep-related quality of life compared to a group of non-surgical class III patients treated with orthodontics alone.

Methods

This study was approved by the Biomedical Institutional Review Board of the University of North Carolina.

Subjects:

Bimaxillary Surgery: Two hundred sixty-two subjects with class III malocclusions who had undergone bimaxillary orthognathic surgery at the University of North Carolina (UNC) Memorial Hospital between 2003 and 2012 were identified from the UNC orthognathic surgery database after accounting for inclusion and exclusion criteria. Subjects were included if they were at least 1 year post-surgery, had current contact information, and were able to understand and read English. The presence of a congenital syndrome led to exclusion from the study.

Orthodontic-Only Control: One hundred seventy-five patients with class III malocclusions who were treated non-surgically in the UNC graduate orthodontic clinic and who met the same inclusion and exclusion criteria as the surgery group were frequency matched to the surgery group based on gender, age, and time since deband.

Each subject was mailed a packet which included a cover letter for informed consent, a HIPAA authorization, an opt-out form, a set of questionnaires, and a business reply envelope. Demographic data, information on OSA diagnosis or management since their class III treatment, and responses to items on three questionnaires to assess OSA risk and quality of life were requested. The questionnaires were created in Teleform® so that returned questionnaires could

be easily scanned, verified, and input into a SAS dataset for analysis. Non-responders were mailed a second and, if necessary, a third packet at monthly intervals.

Questionnaires:

Subjects were asked to report age in years and months, gender (male/female), height in feet and inches, weight in pounds, race/ethnicity, and information on previous OSA diagnosis or treatment. Three sleep questionnaires (Berlin, Functional Outcomes of Sleep-10, and Epworth Sleepiness Scale) were completed by participants in this study to assess OSA risk and sleep-related quality of life. Although the diagnostic gold standard for assessing OSA is overnight polysomnography (PSG), validated disease-specific questionnaires are frequently used as convenient and cost-effective screening tools for OSA.[23]

The Berlin Questionnaire is a validated survey that scores subjects as "high risk" or "low risk" for OSA.[24] In a recent systematic review of validated OSA screening questionnaires, the Berlin had a pooled sensitivity and specificity of, 77% and 74%, respectively.[25] The Berlin Questionnaire is composed of 10 questions divided among 3 symptom categories: snoring, daytime sleepiness, and obesity/hypertension. Patients with frequent and persistent symptoms in any two of the three categories are considered at high risk for OSA. At least 2 affirmative answers in either the snoring or daytime sleepiness categories is confirmation of the presence of that symptom. For the obesity/hypertension category, an answer of "yes" to having hypertension or a body mass index (BMI) of $>30 \text{kg/m}^2$ is considered a positive score. BMI was calculated from the self-reported height and weight.

The Functional Outcomes of Sleep Questionnaire (FOSQ-30) is a valid and reliable 30-item questionnaire that is considered to be the gold standard in assessing the impact of sleepiness

on quality of life.[26] The FOSQ-10 is a shorter version of the original FOSQ-30 and has been shown to be easier to use and to reach the same statistical conclusions as the longer version regarding comparisons in sleep-related quality of life between normal controls and patients with OSA.[27] The FOSQ-10 assesses quality of life via 10 questions measuring 5 subscales: general productivity, activity level, vigilance, social outcome, and intimacy and sexual relationships.[26] Total scores range from 5-20 with lower values suggesting poorer sleep-related quality of life.

The Epworth Sleepiness Scale (ESS) assesses daytime sleepiness and is one of the most widely used sleep assessment questionnaires in clinical settings. Although the ESS has been found to have a low predictive value when used as a screening method for OSA,[28-30] a study using participants from the Sleep Heart Heath Study found excessive daytime sleepiness to be strongly associated with reduced quality of life.[31] The subject rates from 0-3 (0-never, 3- high) his/her chances of dozing off in eight situations that are often encountered in daily life. ESS scores range from 0-24, and a score >10 (i.e. 11+) is considered indicative of excessive daytime sleepiness.[32]

<u>Statistical Analysis</u>

All statistical analyses were conducted using SAS (SAS Institute Inc. Version 9.3 2011. Cary, NC: SAS Institute Inc.)

The orthognathic surgery and orthodontic only groups were compared to assess characteristic differences (age, sex, time since surgery/deband, race, BMI, diagnosis of OSA, prescription for OSA treatment) and to assess whether the groups differed with respect to perception of quality of life and risk for OSA. Descriptive and inferential statistics were used to analyze the data. A chi-square or Fisher's exact test was used to compare categorical variables,

and a Cochran-Mantel-Haenszel row mean score test was used to compare continuous variables between groups. The level of significance was set at 0.05.

Results

Of the 262 surgery subjects sent questionnaires, 78 patients responded (response rate of 29.77%). Surgery participants included 46 females and 32 males with a median age of 27.62 (19.06,36.18). They were all at least 2 years post-surgery with a median time since surgery of 5.43 (2.77,8.09) years. Twenty-four of the 175 subjects in the control group responded (response rate of 13.71%). The control group consisted of 15 females and 9 males with a median age of 22.04 (14.64,29.44) years. They were all at least 1 year post deband (median time since deband was 4.11 (1.80,6.42) years). The two groups were significantly different in median age ($p<0.01$), time since surgery/deband ($p<0.05$), and race ($p<0.01$). Compared to the control group, the surgery group was older, had a longer follow-up time, and was comprised of a higher percentage of Caucasians. No statistical difference between gender and BMI was detected. One participant in the surgery group acknowledged being treated with an oral appliance, but denied having a previous OSA diagnosis. (Table 1)

The Berlin Questionnaire did not reveal any statistically significant difference in the OSA risk assessment between the surgery and orthodontic-only groups nor were there any statistically significant differences between groups in any of the symptom categories (Table 2). Overall, 8.97% of the surgery group and 16.67% of the orthodontic-only group were found to be at high risk for OSA (Figure).

Analysis of the FOSQ-10 indicated no statistically significant difference between the total FOSQ-10 score for the surgery and orthodontic-only with median total scores of 18.27 (16.41,20.13) and 18.13 (15.71,20.55), respectively. The two groups did not differ significantly

in any of the subscales: productivity, activity, vigilance, social outcomes, or intimacy and sexual relations. (Table 3)

The difference in the Epworth Sleepiness Scale scores was significantly different between the surgery and orthodontic-only groups (p<0.05). After excluding those with missing data, the median ESS score for 76 of the BOS group was 6.30 (3.32,9.28) compared to 6.88 (2.41,11.35) for the orthodontic-only group. Both median scores, however, fell within the normal range for daytime sleepiness. When assessed for the proportion of subjects who demonstrated excessive daytime sleepiness, 10.53% of the BOS group and 20.83% of the orthodontic-only group had an ESS total score >10. (Table 4)

Discussion

Sleep disordered breathing, including OSA, is a serious condition associated with increased morbidity and mortality.[3,4] Isolated mandibular setbacks are becoming rare in the United States due to both esthetic reasons and concerns over the risk of airway reduction possibly leading to SDB. Studies on the effects of BOS on sleep function are limited and lead to varying conclusions. In the PSG study of Foltán et al,[20] BOS was found to worsen respiratory parameters with significant decreases in oxygen saturation (SpO2) and nasal airflow measured before and after (mean 8.5 months) surgery. However, in a different PSG study, Hasebe et al[21] was unable to detect significant differences in SDB or changes in SpO2 or Apnea Hypopnea Index (AHI) in patients 6 months after BOS. The investigators did note that 2 patients with very large mandibular setbacks were diagnosed with mild OSA after surgery. Turnbull and Battagel[33] compared overnight pulse oximetry and respiratory noises before and after BOS and found no significant changes despite identifying a reduction in the retrolingual airway diameter in all

patients. In a recent PSG study by Gokce et al,[16] sleep quality and efficiency improved

significantly after BOS (mean 1.4yrs) with significant increases in SpO_2 and decreases in AHI.

One subject in the surgery group acknowledged having used an oral appliance for sleep

apnea, but denied having received a formal diagnosis. Either the patient failed to recall a

diagnosis or was provided the oral appliance in absence of an official diagnosis. The patient also

stated that it had been 2 years since the appliance was used. Since our resources did not allow for

overnight polysomnograms to definitively diagnose OSA in our subjects, we incorporated into

our study a widely used, validated sleep questionnaire, the Berlin Questionnaire, to estimate risk

for OSA to our two study groups.

Our findings of no significant difference in Berlin Questionnaire scores between the BOS

group and the orthodontic-only group is consistent with previous studies that were unable to

demonstrate an increased risk of SDB after BOS. The BOS group scores were also found to be

similar to recent reported OSA risk in population studies. For example, the Berlin Questionnaire

was used in a national sleep poll of 1506 people and 19% of participating adults were found to

meet the criteria for high risk of OSA.[34] In our study, 8.97% of the surgery group was found to

be at high risk for OSA.

While objective measures of SDB have traditionally been reported in the literature,

quality of life assessments are increasingly being recognized as an important outcome variable as

well.[31,35] A number of studies have examined quality of life subsequent to jaw surgery for

dentofacial deformities,[36] however, no studies were identified that explored the impact of Class

III jaw surgeries on sleep-related quality of life. In our study, we used two validated sleep

questionnaires, the FOSQ-10 and ESS, to focus on how BOS may affect patients' perception of

sleep-related quality of life. To our knowledge, this is the first study to assess patients' perception of daytime sleepiness after BOS. With a median time post-surgery time of 5.43 (2.77,8.09) years, our study offered information on subjects with a longer follow up than any previous study that measured sleep outcomes after BOS.

In a recent study evaluating ESS scores between OSA patients and non-OSA patients, the average values found were 10.94 and 7.73, respectively.[30] Although we found a statistically significant difference in ESS scores between our two groups ($p < 0.05$), with the surgery group having a lower median daytime sleepiness score, ESS scores in both groups fell within the normal range. Both groups in our study were close to the reported non-OSA score of 7.73, with the surgery group having a median ESS score of 6.3 (3.32,9.28) and the orthodontic-only group a score of 6.88 (2.41,11.35). It has been estimated that 10-20% of the general population has ESS scores >10.[37] Our results were in that range with 10.53% of the BOS group and 20.83% of the orthodontic-only group having ESS scores >10. The significantly lower ESS score and lower proportion of scores >10 in the surgery group suggest that BOS does not adversely impact daytime sleepiness.

The FOSQ was developed to measure the impact of sleep on quality of life. Higher FOSQ scores reflect better quality of life. In a previous FOSQ-10 study, patients with OSA had an average score of 12.5 while non-OSA participants had an average score of 17.2. [27] In our BOS group, the FOSQ-10 score of 18.27 (16.41,20.13) compared favorably to the reported value in the non-OSA patients. Thus, results from both the ESS and FOSQ-10 in our study suggest that Class III bimaxillary surgery did not significantly affect the patients' sleep-related quality of life post-surgery.

The median age of both of our study groups was younger than we would have liked. Due to the conversion in 2003 from paper charts to the Electronic Patient Record (EPR) at our institution, we were limited in the time frame for which we had current contact information for patients in the UNC surgery database. As such, the median age of both groups was <28 years and may not reflect OSA outcome differences that may occur with increasing age.[38] A well-known risk assessment questionnaire, the STOP-Bang, uses age 50 as a threshold for increased OSA risk.[39] If or how our groups differ after age 50 would be valuable information on clarifying whether BOS is associated with an increased risk of OSA. Although we attempted to frequency match the age of the orthodontic-only group to the age of the surgery group respondents, the median age of the surgery group was approximately five years older which one might have speculated would have magnified a difference in OSA risk if it existed.

The increased follow-up time of approximately 1 year for the BOS group compared to the orthodontic-only group is understandable because up to a year of orthodontic finishing remains after surgery. We were not able to compare deband dates between groups because we did not have access to the deband dates of the surgery group. The majority of the orthognathic surgery patients seen at UNC have their orthodontic treatment carried out by local orthodontists.

The BMI used in this study was calculated from self-reported height and weight values. Although the BMI was not significantly different between groups, any inaccuracies in BMI could also have altered the scoring of the Berlin Questionnaire which uses BMI as one of its variables. Given that the study design did not evaluate patients clinically, obtaining accurate height and

weight data from participants was not possible. The significantly more Caucasians in the surgery group is consistent with the demographics of the surgery patients at UNC.

There was a significant difference in response rate between the BOS group and orthodontic-only group with response rates of 29.77% and 13.71%, respectively. The BOS subjects may have been more likely to participate in our study due to many having previously agreed to participate in an ongoing surgery stability study at UNC. In addition, the BOS subjects may have felt more of an obligation to participate because of the intense emotional and psychological impact that comes from the profound positive changes in function and facial esthetics after surgery.

Conclusions

To our knowledge, this study provides the longest follow-up information to date on the effects of Class III bimaxillary orthognathic surgery (BOS) on sleep disordered breathing. Moreover, this is the first study to assess sleep-related quality of life after BOS. The results of this study suggest that young adults receiving this double jaw surgical procedure for the correction of class III malocclusions are at no greater risk for OSA and/or reduction in sleep-related quality of life compared to patients treated with orthodontics alone. Patients have been shown to be at most risk for SDB if the mandible is setback significantly, preventing adaption to their new respiratory position during sleep.[21] Bimaxillary orthognathic surgery for Class III malocclusions may be able to limit the risk of SDB by minimizing the amount of mandibular setback required and through compensating increases in the nasopharyngeal and velopharyngeal airways from the maxillary advancement.[16,40] Prospective research is needed to evaluate sleep-related quality of life before and after BOS and to examine correlations between PSG data, sleep

questionnaires, and 3D airway parameters. The ability to more clearly identify an orthognathic surgery patient's pre-surgical risk of developing SDB is a goal that would guide surgeons and benefit patients in the future.

Tables

Table 1. Descriptive Statistics for Study Participants			
	Surgery (N=78)	**Orthodontic-Only (N=24)**	**P-Value**
	Median (P25,P75)[a]	Median (P25,P75)	
Variable			
Age	27.62 (19.06,36.18)	22.04 (14.64,29.44)	0.0064
Time Since Surgery / Deband	5.43 (2.77,8.09)	4.11 (1.80,6.42)	0.0346
BMI[b]	25.42 (19.80,27.78)	23.42 (19.06,27.78)	0.1125
Gender	N %	N %	
Male	32 (41.03)	9 (37.50)	0.7580
Female	46 (58.97)	15 (62.50)	
Race			
Caucasian	64 (83.12)	12 (52.17)	0.0023
Other	12 (16.88)	11 (47.83)	
Previous OSA Diagnosis	0	0	-
History of OSA Treatments	1 (1.3)	0	1.0
Oral Appliance	1 (1.2)	0	-

[a] (P25, P75): (25th percentile, 75th percentile).
[b] BMI: body mass index.

Table 2. Berlin Questionnaire Results			
	Surgery	**Orthodontic-Only**	**P-Value**
	N %	N %	
Symptom Categories			
Snoring			
Positive	11 (14.10)	6 (25.00)	0.22
Negative	67 (85.90)	18 (75.00)	
Daytime Sleepiness			
Positive	17 (21.79)	6 (25)	0.74
Negative	61 (78.21)	18 (75.0)	
Blood Pressure/BMI			
Positive	15 (19.23)	2 (8.3)	0.34
Negative	63 (80.77)	22 (91.67)	
Risk Assessment			
Low Risk	71 (91.03)	20 (83.33)	0.29
High Risk	7 (8.97)	4 (16.67)	

Table 3. Functional Outcomes of Sleep Questionnaire-10 Results			
	Surgery	**Orthodontic-Only**	**P-Value**
	Median (P_{25},P_{75})	Median (P_{25},P_{75})	
Subscale Scores			
General Productivity Subscale	3.56 (3.05,4.07)	3.58 (3.0,4.16)	0.7401
Activity Level Subscale	3.47 (2.88,4.06)	3.57 (3.07,4.07)	0.6134
Vigilance Subscale	3.68 (3.24,4.12)	3.71 (3.11,4.31)	0.4702
Social Outcomes Subscale	3.85 (3.42,4.28)	3.83 (3.34,4.32)	0.8906
Intimacy and Sexual Relations Subscale	3.69 (3.04,4.34)	3.47 (2.53,4.41)	0.0569
Total Score[a]	18.27 (16.41,20.13)	18.13 (15.71,20.55)	0.9044

[a] Total score is a mean-weighted item score.

Table 4. Epworth Sleepiness Scale (ESS) Results			
	Surgery	**Orthodontic-Only**	**P-Values**
	Median (P_{25},P_{75})	Median (P_{25},P_{75})	
ESS Score	6.30 (3.32,9.28)	6.88 (2.41,11.35)	0.0492
	N %	N %	
ESS Scores < 10	68 (87.18)	19 (79.17)	
ESS Scores > 10	8 (10.53)	5 (20.83)	

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