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Evaluation of pharyngeal airway space changes after bimaxillary orthognathic surgery with a 3-dimensional simulation and modeling program

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Introduction: The aims of this study were to use 3-dimensional simulation and modeling programs to evaluate the effects of bimaxillary orthognathic surgical correction of Class III malocclusions on pharyngeal airway space volume, and to compare them with the changes in obstructive sleep apnea measurements from polysomnography. **Methods:** Twenty-five male patients (mean age, 21.6 years) with mandibular prognathism were treated with bilateral sagittal split osteotomy and LeFort I advancement. Polysomnography and computed tomography were performed before surgery and 1.4 $\pm$ 0.2 years after surgery. All computed tomography data were transferred to a computer, and the pharyngeal airway space was segmented using SimPlant OMS (Materialise Medical, Leuven, Belgium) programs. The pretreatment and posttreatment pharyngeal airway space determinants in volumetric, linear distance, and cross-sectional measurements, and polysomnography changes were compared with the paired samples *t* test. Pearson correlation was used to analyze the association between the computed tomography and polysomnography measurements. **Results:** The results indicated that setback procedures produce anteroposterior narrowing of the pharyngeal airway space at the oropharyngeal and hypopharyngeal levels and the middle and inferior pharyngeal volumes (P <0.05). In contrast, advancement of the maxilla causes widening of the airway in the nasopharyngeal and retropalatal dimensions and increases the superior pharyngeal volume (P <0.05). Distinctively, bimaxillary orthognathic surgery induces significant increases in the total airway volume and the transverse dimensions of all airway areas (P <0.05). Significant correlations were found between the measurements on the computed tomography scans and crucial polysomnography parameters. **Conclusions:** Bimaxillary orthognathic surgery for correction of Class III malocclusion caused an increase of the total airway volume and improvement of polysomnography parameters. A proposed treatment plan can be modified according to the risk of potential airway compromise or even to improve it with 3-dimensional imaging techniques and polysomnography. (Am J Orthod Dentofacial Orthop 2014;146:477-92)

Orthognathic surgery has gained wide popularity in maxillofacial surgery over the last 30 to 40 years.[1] Recently, mandibular setback surgery has decreased in frequency and is used in less than 10% of mandibular prognathism patients; 2-jaw surgery was preferred in about 40% of patients; maxillary advancement alone is performed in the remaining patients.[2,3] One aspect of these surgeries, which has gained prominence over the last 2 decades, is the effect of the skeletal movements on the pharyngeal airway space (PAS). Many investigations support the idea that after surgical movement of the jaws, changes in the positions of the tongue and hyoid bone also occur, resulting in narrowing of the PAS.[2,4-9] Research in this area shows an association between the PAS and obstructive sleep apnea (OSA).[1,4,10-12] Thus, it can be concluded that any alteration of the facial skeleton that replicates these features can provoke some airway disorder.[1]

Bimaxillary orthognathic surgery for Class III correction could be an alternative to mandibular setback surgery if there is less risk for restriction of the upper airways because a smaller mandibular setback would be needed, and hence more space would be available for the tongue.[13,14] However, most studies have reported a significant reduction of the upper airway.[4,5,7,15,16] These

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studies compared the radiographic changes that patients experienced postoperatively without investigating the possibility of the development of OSA on the basis of polysomnography (PSG). The specificity and accuracy of PSG has made it the standard diagnostic test for OSA.[13,17]

Two-dimensional (2D) lateral cephalograms have traditionally served as the radiographic standard for airway assessment. Although cephalometric measurements are useful for analyzing airway size in the sagittal plane, they do not accurately depict the 3-dimensional (3D) airway anatomy. Finally, although the most physiologically relevant information is obtained from axial images, perpendicular to the direction of airflow, the axial plane cannot be visualized on lateral cephalograms.[4,18] In contrast, an accurate 3D image of the airway can be obtained using computed tomographic (CT) data in the coronal, axial, and sagittal planes.[18]

Although in many studies changes were demonstrated among patients with bimaxillary orthognathic surgery, the correlation between severity and prevalence of sleep apnea and airway parameters has not been examined.[4,5,7,13,14,16] The purposes of this study were to investigate the morphologic changes in PAS after bimaxillary orthognathic surgery in patients with Angle Class III malocclusion using a 3D modeling program and PSG, and to investigate possible correlations among the studied PSG variables and the 3D airway morphology in these patients.

MATERIAL AND METHODS

All patients' written informed consent was obtained. Then, the patients underwent bimaxillary orthognathic surgery at the Dental Sciences Center, Gulhane Military Medical Academy, Turkey. In all patients, based on the cephalometric analysis, anteroposterior maxillary hypoplasia combined with anteroposterior mandibular excess had been diagnosed. The study group consisted of 25 male patients; average age at the time of surgery was 21.6 ± 2.7 years (range, 19-25 years), and mean body mass index values before (T0) and 1.4 ± 0.2 years after (T1) bimaxillary orthognathic surgery were 22.5 and 21.9 kg/m^2, respectively. Patients with breathing problems; craniofacial anomalies; chronic upper airway diseases; previous tonsillectomy, adenoidectomy, genioplasty, or orthognathic surgery; and excessive obesity were excluded from the study.

The surgical technique was identical, and only patients with LeFort I advancement osteotomy without impaction combined with bilateral sagittal split osteotomy with the Obwegeser-Dal Pont method were included in the study. The ranges of maxillary advancement and mandibular setback were 3 to 9 mm (mean, 5.1 ± 2.9 mm) and 5 to 10 mm (mean, 6.9 ± 2.9 mm), respectively. Rigid fixation with titanium miniplates was used in all patients. All patients had maxillomandibular fixation for approximately 2 weeks postoperatively. Each patient had presurgical and postsurgical orthodontic treatment for averages of 7.6 and 5.7 months, respectively.

Every patient underwent a 1-night sleep study at the Sleep Research Center at Gulhane Military Medical Academy, Turkey, before and more than 1 year after surgery. The evaluations showed that 11 patients had no problem related to airway obstruction or snoring during sleep preoperatively (apnea-hypopnea index [AHI] <5), 9 patients were diagnosed as simple snorers (AHI <5), and 5 were diagnosed with mild OSA (5 ≤ AHI ≤15). Sleep parameters were recorded on a 32-channel polygraph (Somno Star Alpha Series-4; Sensor Media, Yorba Linda, Calif). The sleep respiratory information, including AHI, sleep efficiency, sleep stages (weakness, first stage, second stage, third stage, and fourth stage), rapid eye movements, and mean lowest arterial oxygen saturation, was used for data analysis.[13]

This project was approved by the ethics committee of the Institute of Health Sciences of Gulhane Military Medical Academy, Turkey. All CT examinations were performed using a 64-detector CT scanner (Aquilion64; Toshiba Medical Systems, Otawara, Japan), with the patients in the supine position. Scan parameters were 120 kV, 150 mA, and a 400-ms rotation time with a slice thickness less than 0.5 mm and increments of 0.4 mm, using a detector collimation of 64 × 0.5 mm, including the patient's entire head.

The CT scans were obtained 1 week before treatment and more than 1 year after the bimaxillary orthognathic surgery while the patients were supine with the head and neck in a neutral position; the Frankfort horizontal plane was perpendicular to the floor. For a standardized position of the oropharyngeal structures, the examinations were obtained at the end of expiration, without swallowing, in natural head posture, and in centric occlusion, because centric occlusion minimizes the variability of mandibular and soft-tissue measurements often associated with rest position.[19] A cephalostat was not used during the CT data acquisition to allow for the natural position that was unique for each subject. The patients were instructed to hold their breath at end of expiration, when the scan was done. Axial sections were obtained starting from the top of the cranium to the fourth cervical vertebra. All sections were perpendicular to the airway lumen to allow accurate assessment of the linear and volumetric measurements of the PAS.

The data from the CT images were transferred to a network computer workstation on which the 2D