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Morphological changes in the pharyngeal airway of female skeletal class III patients following bimaxillary surgery: A cone beam computed tomography evaluation

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Abstract. Using cone beam computed tomography (CBCT), the present study compared three-dimensional (3D) changes in the pharyngeal airway and surrounding tissues in female skeletal class III patients treated with bimaxillary surgery. Twenty-nine female skeletal class III patients with both maxillary hypoplasia and a mandibular excess underwent bilateral sagittal split ramus osteotomy for mandibular setback combined with Le Fort I osteotomy for maxillary advancement. Volumetric measurements were performed using CBCT scans taken at 1 week presurgery and 6 months post-surgery. The oropharynx volumes and the cross-sectional area behind the soft palate decreased significantly. There was an insignificant change in the volume of the nasopharynx ($P > 0.05$). The hyoid bone moved downward and posteriorly after surgery. The morphology of the soft palate also changed dramatically, with an increase in the length and thickness. Negative correlations were found between the pharyngeal airway space and the position of the hyoid bone. The change in morphology of the soft palate was significantly correlated with the changes in hyoid bone position. These 3D results suggest that bimaxillary orthognathic surgery significantly changes the position of the hyoid bone and the soft palate together with a significant decrease in the pharyngeal airway space in the correction of skeletal class III malocclusion.

Key words: Bimaxillary orthognathic surgery; CBCT; Hyoid bone; Skeletal class III malocclusion; Nasopharynx; Oropharynx.

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Skeletal class III malocclusion, a common dento-maxillofacial deformity, is the result of mandibular prognathism or a maxillary deficiency, or both.[1,2] It not only affects the patient's profile but also their masticatory function and quality of life. Orthodontic treatment alone does not lead to satisfactory results for patients suffering from severe skeletal deformities. Thus, a combination of orthognathic surgery and orthodontic treatment is widely used to improve occlusion, masticatory function, and aesthetics by markedly changing the position of the jaws.[3]

Recently, attention has been paid to the change in position of the hyoid bone and the tongue after orthognathic surgery.[3–7] The consequent narrowing of the pharyngeal airway space (PAS) might worsen the patient's quality of sleep and appears to be a factor in obstructive sleep apnea.[8–11]

It has been reported that less than 10% of class III patients undergo isolated mandibular setback surgery, whereas 40% of class III patients undergo bimaxillary surgery.[12] Compared with isolated mandibular setback surgery, bimaxillary surgery could achieve better coordination of both jaws, improve the patient's profile and masticatory function, and result in less narrowing of the upper airway.[13,14] However, the majority of previous studies on the effects of bimaxillary surgery on the pharyngeal airway in patients with skeletal class III malocclusion have been based on lateral cephalometric analysis, which provides only two-dimensional (2D) Images.[15–17]

Only a few studies have used multi-detector CT (MDCT) to investigate the complex three-dimensional (3D) anatomical structure.[5,6,10,12] Hence, evidence is lacking on airway volume changes after bimaxillary surgery. The introduction of cone beam computed tomography (CBCT) has attracted much attention. CBCT is becoming exceedingly popular due to its many advantages, including improved image quality, accurate 3D reconstruction, and reliable measurements, and it is less affected by metal artefacts compared to traditional CT. However, although the radiation dose of CBCT is lower than that of traditional CT, it is several times higher than that of conventional panoramic and lateral cephalometric imaging. From a radiation-protection point of view, a thyroid collar and the wearing of leaded glasses are recommended when taking CBCT Images.[18,19]

The method of observation and measurement of the pharyngeal airway is limited. Therefore, a study based on 3D evaluations to investigate the changes in nasopharynx, oropharynx, and soft and hard tissues around the pharyngeal airway after bimaxillary surgery, is needed.[7,8] CBCT, which has a lower radiation exposure compared with traditional CT, can be used to evaluate changes in the craniofacial anatomy and upper airway space on a 3D image. This study was carried out on female subjects only because sexual dimorphism has been reported in pharyngeal airway changes, the size of the tongue, soft palate, nasopharynx, and hypopharynx, and the relative position of the hyoid bone.[20]

The purpose of this study was to determine the changes in the pharyngeal airways after bimaxillary surgery in Chinese female patients with skeletal class III malocclusion using CBCT. The results could provide a guide for treatment planning in correcting such skeletal deformities.

Patients and methods

This study recruited 29 female patients (mean preoperative age 23.6 years, range 18–35 years) who were diagnosed with class III skeletal deformities and who underwent bimaxillary orthodontic–surgical treatment (including bilateral sagittal split ramus osteotomy for mandibular setback and Le Fort I osteotomy with maxillary advancement). Patients who had a chronic airway disease, had undergone previous orthognathic surgery, those with marked mandibular asymmetry, habitual snoring, obstructive sleep apnea, chronic upper airway diseases, previous tonsillectomy, or adenoidectomy, and those who had a body mass index above 30 kg/m^2 were excluded.

The orthodontic treatment procedures and bimaxillary surgical procedures were performed and completed in the same hospital. All surgical procedures were performed by the same medical team. Rigid internal fixation was achieved with titanium miniplates and screws. This study was reviewed and approved by the institutional ethics committee. Informed consent forms were signed by all patients or their parents. After treatment, all 29 patients were satisfied with their teeth and profile. The mean anterior movement of the maxilla was 3.5 ± 0.8 mm at the anterior nasal spine (ANS). The mean posterior movement of the mandible was 5.8 ± 1.7 mm at the pogonion. All treatment objectives were achieved. The anterior crossbite was corrected and satisfactory dental alignment, normal overjet and overbite, and ideal class I molar and canine relationships were established on both sides. The overall facial balance was greatly improved.

CBCT examination

All patients underwent a CBCT examination (Galileos; Sirona, Bensheim, Germany) for assessment of the upper airway volume and surrounding tissue changes within a week prior to surgery (T_0) and at 6 months after surgery (T_1). The CBCT scans were performed in the department of radiology by the same radiology technicians. The patients were seated in the upright position with the tongue in resting position and the mandible in centric occlusion position. The head and neck were supported and fixed with a hard pillow while taking the CBCT. The patient's Frankfort horizontal plane (FHP) was parallel to the floor. The slice thickness was 150 μm for the 3D reconstruction image (85 kV, 5–7 mA). The resulting CBCT images were stored in the workstation computer and converted into DICOM format (Digital Imaging and Communication in Medicine). Each subject was scanned from the Frankfort horizontal line to the hyoid bone. The CBCT data were analysed with Mimics 10.01 software (Materialise, Leuven, Belgium).

Measurement

The nasopharynx is located behind the nasal cavity and above the soft palate; anteriorly, it is connected to the nasal cavity, and posteriorly, it continues downward to the oropharynx. The landmarks of the nasopharynx for analysis were as follows: the most posterior point of the pterygomaxillary fissure (PT point) and the posterior nasal spine (PNS). The oropharynx is located behind the oral cavity and above the epiglottis. The oropharynx is defined as the airway space between a plane parallel to FHP passing through PNS and a plane parallel to FHP passing through the epiglottis. The pharynx was defined as the sum of the nasopharynx and the oropharynx (Fig. 1).

The cross-sectional area (CSA) of the airway on axial plane was analysed by CBCT scans to evaluate treatment changes. The landmarks and planes are shown in Figs. 1 and 2.

The landmarks, planes, and measurements for the linear analysis of the hyoid bone and soft palate on CBCT are shown in Figs. 3 and 4; this was based on the methods of Park et al.[10] and Muto et al.[11]