HE004

Evaluation of pharyngeal airway dimension changes after bimaxillary surgery in a group of Thai patients using cone-beam computed tomography

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Abstract

The purpose of this study was to evaluate airway dimensional changes in Thai patients who underwent Le Fort I osteotomy with maxillary advancement and mandibular setback surgery to correct the class III dentofacial deformities. This prospective study was performed on 13 patients who underwent Le Fort I osteotomy advancement and mandibular setback surgery. Cone-beam computed tomography (CBCT) scans were taken at 2 time points: preoperative and 3-month postoperative. The changes of pharyngeal airway space (PAS) dimension in anteroposterior length (APL), lateral transverse width (LTW) and cross-sectional area (CSA) in 4 levels were calculated. The minimal cross-sectional area (minCSA) was also recorded. Statistical analysis was performed. After surgery, the APL at posterior nasal spine (PNS) level increased significantly whereas the APL at the second cervical vertebra (CV2) level decreased substantially. No statistically significant differences were found for other linear measurements. The CSA in all levels insignificantly changed but the minCSA decreased significantly after surgery. In conclusion, bimaxillary surgery for the correction of Class III malocclusion affected the soft tissue morphology by increasing the upper part and decreasing the lower part of the airway. The APL changed significantly but the LTW remained the same. The narrowest area of airway decreased substantially after surgery.

Keywords: Bimaxillary surgery, cone-beam computed tomography, orthognathic surgery, pharyngeal airway space

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Introduction

Skeletal class III malocclusion is one the most common problems in Asian population (Susami, Asai et al. 1972, Chang 1985, Kang and Ryu 1992, Chang, Liu et al. 2014). Growth disharmony between mandible and maxilla produces a concave facial profile and affect patient's masticatory function. Orthodontic treatment alone does not lead to satisfactory functional and esthetic results; therefore, a combination of orthodontic treatment and orthognathic surgery is required to correct this deformity (Bailey, Haltiwanger et al. 2001).

Class III malocclusion with skeletal discrepancies can be corrected with mandibular setback surgery with or without maxillary advancement depending on the degree of maxillary deformity. The important aspect of mandibular setback is that it may decrease the oropharyngeal airway which can compromise patient's airway leading to obstructive sleep apnea (OSA) (Demetriades, Chang et al. 2010).

OSA is characterized by a complete or incomplete repeated collapse of the pharyngeal airway lasting at least 10 seconds during sleep (Malhotra and White 2002). Persons with OSA are prone to systemic and pulmonary hypertension and cardiac arrhythmias (Hardinge 2008). Fragmentation of sleep can reduce neurocognitive function, increase risk of motor vehicle and occupational accidents, and all in all, decrease quality of life.

Changes of the dimensions of the pharyngeal airway space (PAS) after surgery have been the subject of several studies regarding the importance of the volume change of the PAS to the quality of life. Conventionally, pharyngeal airway analyses are made by using lateral cephalograms (Johnston and Richardson 1999, Bettega 2000, Tselnik and Pogrel 2000, Samman, Tang et al. 2002). However, it is difficult to quantify pharyngeal airways by using only conventional two-dimensional images. Lateral cephalograms cannot capture the changes in the lateral direction. In contrast, cone-beam computed tomography (CBCT) has many advantages including the details of lateral dimensions, cross-sectional areas and volumes. Therefore, the advances and availability of CBCT imaging allows pharyngeal airway to be accurately evaluated (Lenza, Lenza et al. 2010).

Objective of the study

The purpose of this study was to evaluate pharyngeal airway dimensional changes in a group of Thai patients who underwent Le Fort I osteotomy with maxillary advancement and bilateral sagittal split ramus osteotomy (BSSRO) setback surgery to correct the class III dentofacial deformities.

Materials and methods

Patients

The patients were recruited from the Department of Oral and Maxillofacial Surgery, Faculty of Dentistry, Chulalongkorn University, Bangkok, Thailand. Thirteen patients (aged 18-40 years) with class III skeletal deformity who underwent Le Fort I osteotomy with maxillary advancement and BSSRO setback were included in this study. None of the patients had craniofacial anomalies, trauma or respiratory diseases. The patients who had airway pathology, history of correction of airway problems or previous chin augmentation were excluded from the study.

Surgery

Le Fort 1 osteotomy with maxilla advancement and BSSRO mandibular setback were perfomed for all patients by one oral and maxillofacial surgeon according to the orthognathic treatment plan. The standard surgical procedures were performed under general anesthesia. Titanium microplates and screws were used for rigid internal fixation at the maxilla while miniplates and screws were used at the mandibular osteotomy sites. Maxillomandibular fixation was applied for 2 weeks. All patients were prescribed preoperative antibiotic and high dose steroid, and subsequently, steroid and analgesics were prescribed post-operatively.

Cone-beam computed tomography (CBCT)

Preoperative (T0) and 3-month postoperative (T1) CBCT scans were taken for all patients using Planmeca ProMax 3D Mid (Planmeca Oy, Helsinki, Finland). The standard scanning protocol was set at 90 kV, 10 mA, 27 seconds and 17x20 cm field of view. The CBCT scans were done by positioning the Frankfurt horizontal (FH plane) of the patients parallel to the floor. The patients were told not to swallow while scanning and to breathe normally, maintain natural head position and keep the teeth in occlusion during the scanning.

The three-dimensional (3D) images were reconstructed and then slightly reoriented by using FH plane as a horizontal reference plane. Then, linear dimensions and cross-sectional areas (CSA) of the PAS were measured and calculated on Romexis® software (Planmeca Oy, Finland).

The anatomic boundaries of pharyngeal airway in this study are modified from the study of Lee et al (Lee, Chun et al. 2012). The posterior nasal spine (PNS), the posterior wall of the pharynx, the lateral wall of the pharynx were defined as the anterior border, the posterior border, the lateral border, respectively. The superior border was a plane parallel to the FH plane passing through the most superior point of the pharynx. The inferior border was a plane parallel to the FH plane passing through the most concave point of the anterior and inferior wall of the third cervical vertebra (CV3).

The CSA, anteroposterior length (APL) and lateral transverse width (LTW) at PNS plane, the first cervical vertebr (CV1) plane, the second vertical vertebra (CV2) plane and CV3 plane were measured (Table I). The minimal cross-sectional area (minCSA), which was defined as the narrowest part of the airway, was assessed as well. The same investigator did the measurements twice after 4-week time interval.

Statistical anlysis was performed on SPSS software version 22.0 (SPSS Inc, Chicago). The reproducibility of measurements was done by using intraclass correlation coefficient (ICC). The Wilcoxon matched pairs test was used to compare parameters between pre- and post-operative. The significant level was set at $p < 0.05$.

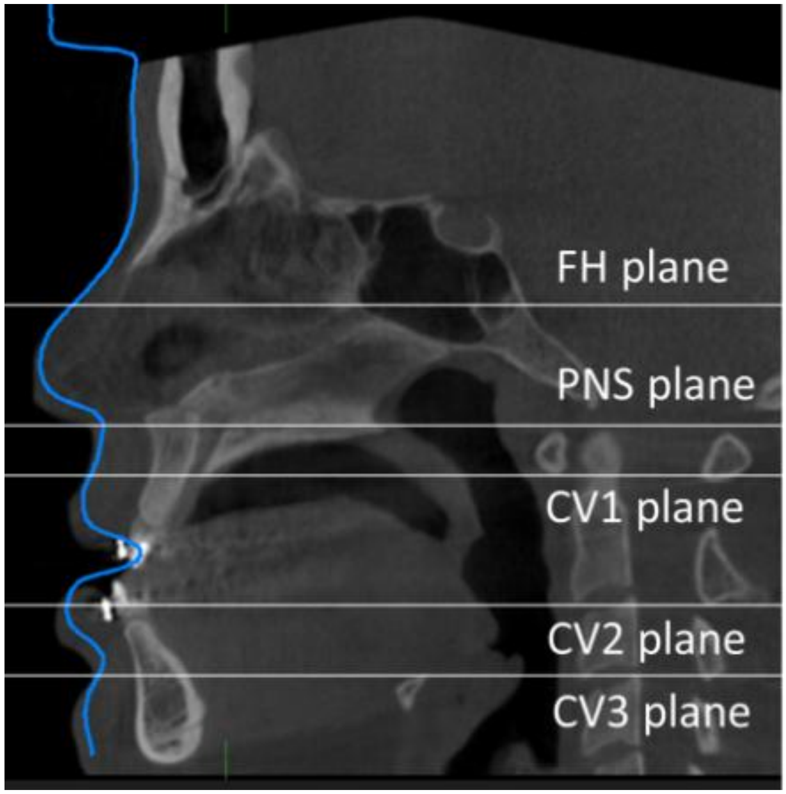

Fig.1 Reference planes

Table I Definition of reference planes

Planes	Definitions
FH plane	The plane passing through the inferior margin of the left orbit (the point called the left orbitale) and the upper margin of each ear canal or external auditory meatus (a point called the porion)
Mid-sagittal plane	The plane perpendicular to the FH plane passing through Nasion and Basion.
PNS plane	The plane parallel to the FH plane passing through the PNS level in mid-sagittal plane
CV1 plane	The plane parallel to the FH plane passing through the most anterior inferior point of the anterior arch of the atlas in mid-sagittal plane
CV2 plane	The plane parallel to the FH plane passing through the most

	anterior inferior point of the body of the 2nd cervical vertebra in mid-sagittal plane
CV3plane	The plane parallel to the FH plane passing through the most anterior inferior point of the body of the 3rd cervical vertebra in mid-sagittal plane

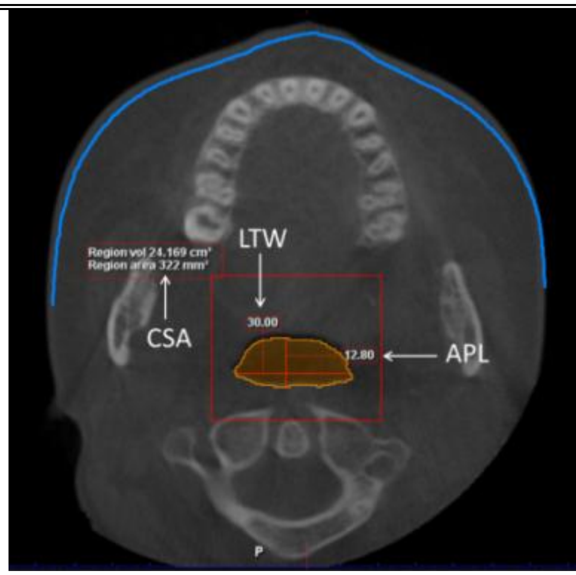

Fig.2 Measurements in each plane of the pharyngeal airway :APL, anteroposterior length; LTW, lateral transverse width; CSA, cross sectional area.

Results

The samples consisted of 13 patients with skeletal class III malocclusion (2 men and 11 women, aged 18–40 years with a mean age of 25.46 ± 7.48 years, BMI 20.51±2.00) who underwent bimaxillary surgery at the Department of Oral and Maxillofacial Surgery, Chulalongkorn University Dental Hospital. This study was reviewed and approved by the Human Research Ethics Committee of the Faculty of Dentistry, Chulalongkorn University (HREC-DCU 2016-089).

All subjects underwent pre- and postoperative orthodontic treatment and received the same standard surgical procedure. In each case, during proceeding Le Fort I osteotomy advancement, if there was maxilla canting, the maxilla would also be corrected to the proper occlusal plane then the BSSRO procedure was performed to setback the mandible.

The intraobserver reproducibility showed the ICC ranged from 0.994 to 1.000. The general morphologic changes in the airway space were identified with the anteroposterior and lateral diameters and CSA in the PNS, CV1, CV2 and CV3 axial planes. The linear changes and CSA were compared between T0 and T1 (Table II). The APL had increased in PNS plane. In contrast, the APL in CV1, CV2 and CV3 planes had decreased. But only the changes in PNS and CV2 plane yielded statistically significant result ($p < 0.05$). The lateral diameter had decreased in all planes but there was no statistically substantial difference. The CSA in PNS plane had insignificantly increased while the CSA in CV1, CV2 and CV3 planes had insignificantly decreased. The minCSA significantly decreased ($p < 0.05$).

Table II Comparison of the cross-sectional dimension of the pharyngeal airway before and after surgery in each plane

Measurements	T0		T1		Differences		P-value
	Mean	S.D.	Mean	S.D.	Mean	S.D.	
PNS-APL	23.43	2.705	24.46	2.90	1.03	1.19	0.013*
PNS-LTW	31.80	5.49	31.02	4.95	-0.78	1.69	0.098
PNS-CSA	647.92	141.66	653.31	148.20	5.38	38.13	0.642
CV1-APL	15.63	4.025	15.17	3.05	-0.46	2.53	0.292
CV1-LTW	33.00	5.24	32.74	4.33	-0.26	1.74	0.599
CV1-CSA	433.00	157.34	411.62	105.50	-21.38	72.68	0.136
CV2-APL	15.63	3.14	13.94	3.98	-1.69	2.85	0.045*
CV2-LTW	29.15	4.52	28.77	4.55	-0.38	2.54	0.562
CV2-CSA	364.08	111.64	333.77	130.24	-30.31	75.70	0.173
CV3-APL	16.74	3.70	15.02	5.08	-1.72	4.12	0.151
CV3-LTW	32.40	3.61	31.82	4.34	-0.58	2.91	0.554
CV3-CSA	361.85	75.29	327.85	143.83	-34.00	95.54	0.249
minCSA-APL	13.65	3.25	12.62	3.11	-1.03	2.34	0.107
minCSA-LTW	27.85	5.58	26.89	6.56	-0.95	3.52	0.249
minCSA	315.85	113.96	280.31	113.93	-35.54	55.16	0.036*

Note: T0 indicates before surgery. T1 indicates 3 month after surgery.

* $p<0.05$ with Wilcoxon matched pairs test

Discussion

The narrowing of the pharyngeal airway might be one of the predisposing factors for developing OSA. Therefore, the change of pharyngeal airway after orthognathic surgery should be concerned (Gokce, Gorgulu et al. 2014). In this study, the changes of pharyngeal airway dimensions after orthognathic surgery were evaluated. Several investigators have discussed about the limitations of airway studies in lateral cephalogram (Degerliyurt, Ueki et al. 2009, Jakobsone, Neimane et al. 2010, Gokce, Gorgulu et al. 2012). Identifying the exact soft-tissue contours is difficult using two-dimensional images. On the other hand, CBCT, which is 3D technique, has the benefit that can provide more information of hard and tissue structures. This technique can assess not only the linear projections but also visualization of CSA of the airway at any positions along its length and volume measurements.

Normally, the posture and position of the head are correlated to the dimension of airway space (Muto, Yamazaki et al. 2008). The pharyngeal CSA decreased when the patients change from the upright to the supine position (Fouke and Strohl 1987). Changes of body posture cause postural effects of the tongue that affect upper airway size. The retropalatal airway becomes narrow and the retroglossal airway widens from an erect to supine position (Chen, Li et al. 2002). All CBCT scans used in this study were taken with the patients in an upright position to minimize differences in the airway dimension from a change in body posture. Also, different breathing stages have an impact on the pharyngeal airway dimension measurements. The patients were instructed to breathe gently and not to swallow during the scanning to reduce difficulty to obtain T0 and T1 scans at the same breathing stage.

Moreover, the reference points at soft tissue in previous studies (Hong, Park et al. 2011, Gokce, Gorgulu et al. 2014, Uesugi, Kobayashi et al. 2014) sometimes varied according to the imaging conditions (breath, swallowing, and position). However, in this study, the reference planes dividing the PAS were set at the fixed cervical vertebra to avoid the misinterpretation from the identification of soft tissue. Thus, it was possible to compare and analyze linear dimensional changes and cross sectional areas at the same level accurately.

There was no consensus in the literatures that has been established regarding the standard pattern of airway division. Changes in PAS according to bimaxillary surgery may be inconsistent among reports because the measurements (planar, linear, and volumetric) differ depending on the definition of the airway.

Studies using medical computed tomography (MDCT) or CBCT to calculate planar measurements have provided the linear dimension and CSA at multiple levels (Degerliyurt, Ueki et al. 2008, Degerliyurt, Ueki et al. 2009, Jakobsone, Neimane et al. 2010, Park, Kim et al. 2010, Hong, Park et al. 2011, Park, Kim et al. 2012). Changes after bimaxillary surgery are less obvious than mandibular setback surgery alone.

Significant changes in linear dimensions were not frequently published (Degerliyurt, Ueki et al. 2008, Lee, Chun et al. 2012, Park, Kim et al. 2012). As no significant lateral changes have been reported, the effect can be largely noticeable in the anteroposterior dimension. In this study, the lateral dimension of the airway decreased after surgery, but there were no significant changes in any levels. The size of the pharyngeal airway in anteropostrerior dimension increased significantly after surgery at PNS level due to the advance of maxilla. The substantial decrease in anteroposterior dimension was found at CV2 level while there were the insignificant decreases at CV1 and CV3 levels. In previous studies, Uesugi et al. (Uesugi, Kobayashi et al. 2014) and Hatab et al. (Hatab, Konstantinovic et al. 2015) reported the insignificant increase of anteroposterior dimension of pharyngeal airway at PNS level. Lee et al. (Lee, Chun et al. 2012) found that APL at CV1 level decreased significantly after Le Fort I impaction with intraoral vertical ramus osteotomy (IVRO) while Park et al.(Park, Kim et al. 2012) reported a significant increase at the same level after Le Fort I with maxillary advancement and BSSRO setback. At CV2 level, Lee et al. (Lee, Chun et al. 2012) and Park et al. (Park, Kim et al. 2012) found an insignificant decrease in APL but Degerliyurt et al.(Degerliyurt, Ueki et al. 2008) reported a substantial decrease after bimaxillary surgery. At CV3 level, the APL decreased significantly (Degerliyurt, Ueki et al. 2008, Park, Kim et al. 2012).

In previous CSA measurements, regarding the cross-sectional areas from CV1 to CV4, significant change was not observed except for a decrease in CV4 that existed in the long term (Degerliyurt, Ueki et al. 2008, Hong, Park et al. 2011, Lee, Chun et al. 2012) .The measurement remained unchanged at the tip of the uvula and epiglottis and in the vallecular (Jakobsone, Neimane et al. 2010, Hong, Park et al. 2011, Goncales, Duarte et al. 2014) .

In this study, the CSA at PNS level increased while the CSA decreased at CV1, CV2 and CV3 but all of the measurements were not significant. Physical restriction by the mandibular setback could be the explanation of the decrease in the lower part. Widen pharyngeal airway at the level of the PNS from the anterior movement of the maxilla was observed in patients receiving bimaxillary surgery that compensated for the changes of the pharyngeal airway resulting from setback movement of the mandible. This result concurred with the results of previous studies (Degerliyurt, Ueki et al. 2008, Jakobsone, Neimane et al. 2010, Lee, Chun et al. 2012). Previous studies showed that the changes in the pharyngeal airway after surgical correction of Class III deformities occurred more frequent in the anteroposterior direction (Kawamata, Fujishita et al. 2000, Degerliyurt, Ueki et al. 2008), whereas the lateral width remained the same after bimaxillary procedures or slightly reduced following isolated setback (Kawamata, Fujishita et al. 2000, Degerliyurt, Ueki et al. 2008, Jakobsone, Neimane et al. 2010). The provided explanation was that the pharyngeal lumen had an elliptical shape with the lateral width being the longer axis; therefore, the resulting CSA did not significantly change.

Regarding OSA, the information about minCSA is important. The reason is the degree of constriction is the most critical factor in the resistance to airflow due to Poiseuille's law. If the minCSA is very small, there is more chance to cause apnea. An upper airway size of approximately 50 mm^2 or less has been shown to be associated with sleep apnea (Galvin, Rooholamini et al. 1989, Bhattacharyya, Blake et al. 2000). In this study, although the minCSA significantly decreased after bimaxillary surgery, the values are well above the range described for patients with OSA. However, surgeons should keep in mind about the chance to cause the patient become OSA after surgery.

The limitation of this study was the small sample size. Moreover, this study lacked the information about the patients' sleep tests before and after surgery. More research is needed to evaluate and correlate all factors related to OSA. In addition, the relationship of the distance of jaw displacement and pharyngeal airway change should be evaluated in further studies for surgeons can decide the appropriate treatment plan for the patients.

Conclusion

The study revealed that bimaxillary orthognathic surgery for patients with skeletal Class III malocclusion affected the morphology of the upper airway. The significant changes were largely noticeable in the APL dimension while LTW and CSA remained the same. The narrowest area of airway decreased substantially after surgery. Therefore, surgeons should concern about the airway changes that may occur following orthognathic surgery in order to prevent excessive airway constriction and avoid the development of iatrogenic OSA.

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