Morphological Changes of Pharyngeal Airway After Incisor Retraction in Bimaxillary Protrusion Growing Patients with Maximum Anchorage

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Abstract

Objective: To evaluate the changes of morphology in the pharyngeal airway after incisor retraction in bimaxillary protrusion growing patients with maximum anchorage by three-dimensional (3D) registration and evaluation.

Study Design: Cone beam computed tomography (CBCT) scans of 32 growing patients with bimaxillary protrusion and 32 age- and gender-matched controls were reconstructed. A student t-test was used to compare morphological changes of pharyngeal airway between two groups.

Result: After treatment, both groups showed a general enlargement in pharyngeal airway dimensions. There showed no statistical differences in the change of pharyngeal volume, CSA, LAT/AP and GH between the two groups. However, the experiments showed a significant decrease in the ration of palatopharynx area (PPA) to glossopharynx area (GPA) compared with the control group. A significant correlation was observed among the PPA/GPA, the incisor retraction amount and the hyoid backward amount.

Conclusion: Growing bimaxillary protrusion patients with maximum anchorage showed a potential trend of slower growing speed of palatopharynx than glossopharynx, which may be caused by the backward of the hyoid and retraction of the central incisor.

Keywords: Pharyngeal airway; CBCT; 3D registration; Bimaxillary protrusion.

Introduction

Bimaxillary protrusion is a common condition characterized by prominent and proclined upper and lower incisors and a protruding profile [1]. In order to acquire a more aesthetics profile, those patients usually seek orthodontic care. And because patients want a straight profile, many orthodontists believe it is necessary to extract premolars, and to place miniscrews to retract incisor with maximum anchorage [2]. Though occlusal harmony and aesthetic appearance is the aim of orthodontic treatment, more attention is being paid to the shape of dentofacial complex, especially the pharyngeal airway. According to varies studies [3-6], the pharyngeal airway plays a key role in ventilation, swallowing,
The aim of this retrospective study was to clarify the change of pharyngeal airway during incisor retraction in growing bimaxillary protrusion patients with maximum anchorage by 3D registration and evaluation. The individual differences in pharyngeal airway between pre- and post-treatment were also evaluated.

Materials and Methods

Subjects

This research was approved by the Research Ethic Committee from the Stomatology School of Shandong University (Protocol number: GR201801). In this retrospective study, 32 individuals who met the four following criteria were randomly selected from Orthodontic Department of Shandong Stomatology Hospital between 2016 and 2018:

- Chinese growing patients (15 boys aged 10.65±1.40 years and 17 girls aged 11.14±1.47 years) with full dentition at initial (excluding the third molars).
- Informed consent including the possible damage of CBCT radiation lesion and miniscrew-methodologies was acquired.
- Pretreatment with Class I molar relationship, interincisal angle less than 124°, upper incisor protrusion more than 7.7 mm and lower incisor protrusion more than 3.0 mm.
- Patients who had medical history including craniofacial deformity, hypopharynx disease, sleep apnea syndrome, adenoidectomy and tonsillectomy were excluded.
- Four first premolars were extracted and four miniscrews (Cibei Medical Company, Ningbo, China. No.121222) were placed as the anchorage for the translational retraction of the incisors. The patients were treated using oriental preadjusted appliance KOSAKA slot brackets (OPA-K, Tomy, Fukushimaken, Japan. No.936-102L 022), and force of 150g per side of elastic chains were applied from the miniscrew to the upper and lower crimpable hooks to retract the maxillary and mandibular teeth (Figure 1).

As the inherent inaccuracies of two dimensional (2D) lateral cephalograms [19,20], three dimensional (3D) analysis was preferred in assessment of hard and soft tissue morphology [21-23]. Compared with computed tomography (CT) imaging techniques, CBCT has been used to evaluate upper airway morphology with its ever wider adaptation, which is proven to provide sound and reproducible results [24-26]. 3D models can then be reconstructed based on the CBCT images. With the accurate registration method, pre- and post-treatment 3D models can be superimposed to examine the morphological changes [27].

Figure 1: Miniscrews were placed in the interradicular locations between the first molar and second premolar at the attached gingival level height. Miniscrews of pre-treatment (figure A) and post-treatment (figure B) were shown.
CBCT data acquirement

The whole skull CBCT scanning with 0.4 mm slices was performed in Week One after implanting all miniscrews (Time One: T1), and post-treatment (Time Two: T2) with natural head posture and maximum intercuspation during the awake periods of patients at the end of eupnoea respectively, which were undertaken in the same way by 3D eXam scanner (Kavo Dental GmbH, Bieberach, Germany. No. ICU081294) at a 0.30-voxel resolution. All patients were asked to maintain the resting position of the tongue tip, which was in contact with the anterior part of the hard palate without touching the anterior teeth. The CBCT scanning was performed perpendicularly to the apicalcoronal direction on each slice with the lateral scanogram of the head position (scan time: 8.9 seconds, 120 kV, 5 mA). The data were exported as Digital Imaging and Communications in Medicine (DICOM) format.

3D visual model reconstruction

All 3D models were constructed from CBCT images. The bone, teeth and pharyngeal airway morphology structures were respectively separated by threshold based on Hounsfield Unit (HU) in MIMICS 16.01 (Materialism's Interactive Medical Image Control System) software. In order to include the alveolar regions and exclude tooth structure, a lower limit of 392 HU and a higher limit of 1900 HU were defined. The tooth excluding bone structure was separated with a lower limit of 1500 HU and a higher limit of 3725 HU, and the pharyngeal airway part was around -1024 HU to -259 HU. The separated and independent masks were created for each part, which generated following individual geometrical files and 3D models. All 3D masks were exported as Stereolithography (STL). To build 3D models of the pharyngeal airway before and after incisor retraction, T1 and T2 CBCT data were imported into MIMICS 16.01 software. Once segmented, all of the sections were also reconstructed respectively (Figure 2A).

Registration of pre- and post-treatment models

The investigator used landmark-derived superimposition method in order to make the surfaces of the two models approximate to each other as much as possible. Then, the investigator used ICP (Iterative closest point) algorithm based regional registration in Mimics with the craniobase as the reference [28]. After registration, we imported the saved mimics file into 3-matic Research 9.0 (Materialise, Leuven, Belgium). Accuracy and reproducibility of the superimpositions were assessed only in the crown portion of the model to measure RMS (Root mean square) value between the models [29,30]. A color scale image, a mean, and a standard deviation can be obtained. Then the RMS can be via this formula: \[\sqrt{\bar{x}^2 + \sigma^2},\] where \(\bar{x}\) is mean, and \(\sigma\) is the standard deviation. A registration with a RMS value ≤0.4 mm was considered successful, which is the size of the voxel generated by the CBCT machine.
Table 1: Descriptive statistics and comparison of pharyngeal airway between T1 and T2 in two groups (T1, pretreatment; and T2, post-treatment).

<table>
<thead>
<tr>
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<th>Experiments (n=32)</th>
<th>Controls (n=32)</th>
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<td></td>
<td>(T2-T1)/T1% (percentage)</td>
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<tr>
<td></td>
<td>Mean</td>
<td>SD</td>
<td>Mean</td>
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<tr>
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<td>19.42</td>
<td>28.13</td>
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<tr>
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<td>8.61</td>
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<tr>
<td>PPA/GPA</td>
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<td>2.14</td>
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Figure 3: The pre- (T1) and post-treatment (T2) data of patients was registered. A: STL registration with cranial base. B-C: Registration of pre- (green) and post- (red) models. D-F: Pre- (purple) and post- (yellow) models of the teeth. G-I: Changes in the teeth, cross-sectional areas of the pharyngeal airway and displacements of the hyoid bone between the T1 and T2 models were measured.

3D Measurement

In this study, the palatopharynx was defined as the region between the hard palate and the end of the uvula; the glosso- and epiglottis; and the hypopharynx was below the epiglottis (Figure 2B). The anterior boundary of the pharyngeal airway was defined by soft palate, base of the tongue, and the anterior wall of the pharynx [31,32]. Three cross-sectional planes were used to evaluate the area of the airway and identify on the 3D model [18]. The area measurements included NP, SP, and EP area (Figure 2C). The landmarks, cross-sectional planes and pharyngeal airways identified on each 3D model were shown in Supplementary Table 1.

After 3D reconstruction, the pharyngeal volume (VOL) and cross-section area (CSA) were obtained. The ratio of lateral width (LAT) to anteroposterior width (AP), and palatopharynx area (PPA) to glosso- and epiglottic area (GPA) was computed in construction of cross-section. After registration and numerical simulation, the changes of pharyngeal morphology and flow field were obtained in 3D geometric models for inter-patient comparison (Figure 3). The hyoid retraction in the horizontal (X-H) and vertical (Y-H) direction, and the central incisor retraction at edge (X-ICE) and root (X-IRA) in the horizontal direction, and the genial tubercle to hyoid distance (GH) were measured in 3D registration models. All parameters mentioned are defined in Supplementary Table 2 [33]. Every subject was measured for three times by the same investigator, and then the measurements were averaged.

Statistical Analysis

All collected data were organized, and descriptive statistics (means, standard deviations, and ranges for pre- (T1) and post-treatment (T2) records) were performed in SPSS software (version 22.0, SPSS Inc., Chicago, IL, USA). For each individual, variables of pharyngeal airway, hyoid and central incisor was described as (T2-T1)/T1% and differences between controls and experiments were assessed with t-tests. Relationships among variables were assessed by the Pearson correlation coefficient. The error of the method, which was based on double measurements at a 2-month interval, was calculated for 32 randomly selected patients for 3D linear measurements (as described by Houston [34]) and was calculated as follows: \( s = \sqrt{\sum (d)^2 / 2n} \) (where ‘d’ indicates deviations between the two measurements and ‘n’ indicates
the number of paired objects). The error for 3D linear and cross-sectional area measurement was 0.26 mm and 0.13 mm² (SDs of d are 0.14 mm and 0.07 mm²), respectively [23]. The statistical difference was not significant between the two measurements by t-test at the significance level of α=0.05.

Results

Descriptive statistics and comparison of pharyngeal airway between T1 and T2 in two groups is presented in Table 1. The amount of upper incisor retraction in the incisal edge and the apex were 7.52±1.72 mm and 2.75±1.46 mm respectively, and the position of the hyoid was backward by 2.47±0.67 mm and 8.08±2.69 mm in the horizontal and vertical direction, respectively. Both groups showed an increase in VOL, CSA, LAT/AP and GH. The ratio of PPA/GPA reduced significantly in the experiments, whereas raised obviously in the controls, with a statistical significance for this value. The change amount of pharyngeal VOL, CSA showed no statistical differences between two groups. A significant correlation was observed in central incisor retraction amount in edge, the hyoid backward amount in the horizontal direction and the change of PPA/GPA (0.8<|r|<1, p<0.05) (Table 2).

Discussion

In this study, we evaluated the pharyngeal morphology in growing bimaxillary protrusive patients after incisor retraction with maximum anchorage via CBCT data. As patients involved in the research are in the growth period, the upper airway of both groups became larger, wider, and longer after treatment. The change amount of pharyngeal dimension after incisor retraction showed no differences between two groups. However, the ratio of PPA/GPA in the experimental group is significantly decreased compared with the control group. Besides, a significant correlation is observed among the amount of teeth retraction, hyoid backward movement and PPA/GPA in the experimental group, indicating that the distal movement of incisor may lead to a relative constrict in palatopharynx.

The retraction movement of the front teeth group via maximum anchorage may pose a substantial effect on the various tissues, including the constrictive dental arch and the shrinking oral cavity. Meanwhile, from the structural point of view, the palatopharynx is defined as the region between the hard palate and the end of the uvula, which is in accordance with the position of dentition. When incisors were retracted by maximum anchorage in growing patients, the palatopharynx region was expected to change less when compared to the control group. In addition, pharyngeal airway is an irregular soft tissue lumen and bone scaffold [35], the main reason of the decrease of PPA/GPA may be the slower growing speed of palatopharynx than glossoopharynx, which is caused by the backward of the hyoid and retraction of the central incisor.

Large samples can figure out the potential trend of population, but were more difficult to collect. On the contrary, individual evaluation seems to be clearer to illustrate the personal changes, which is one of the innovative clinical significances of this research. However, the observation of long-term stability is still needed for each patient in future. According to the data in this study, we explored that orthodontists should not be only concerned with the dentofacial type, but the mechanobiological response of the pharyngeal airway.

Conclusion

The central incisor retraction with maximum anchorage may lead to a relative constrict in palatopharynx and thus a change in pharyngeal shape in growing bimaxillary protrusion patients.

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Author Contributions

Hongchen Liu designed the research, reviewed and revised the manuscript and approved the final manuscript as submitted, and obtained funding for the project. Qingyuan Guo and Dongxu Liu collected the data, carried out the research, measured and analyzed the data. Liang Li analyzed and discussed the results, and drafted and revised the manuscript. Hong Liu and Pengyan Qiao collected the data, reviewed and revised the manuscript and approved the final manuscript as submitted. Rong Zhang collected the data, and carried out the research. Lingling E provided the CBCT scanning data. All authors approved the final manuscript as submitted and agree to be accountable for all aspects of the work.
Additional Information

Competing financial interests: The authors declare no competing financial interests.

References


