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Correlation between hyoid bone position and airway dimensions in Chinese adolescents by cone beam computed tomography analysis

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Abstract. This study aimed to investigate the correlation between upper airway dimensions and hyoid bone position in Chinese adolescents based on cone beam computed tomography (CBCT) images. CBCT images from a total of 254 study subjects were included. The upper airway and hyoid bone parameters were measured by Materialism's interactive medical image control system (MIMICS) v.16.01 (Materialise, Leuven, Belgium). The airway dimensions were evaluated in terms of volume, cross-sectional area (CSA), mean CSA, length, anteroposterior dimension of the cross-section (AP), lateral dimension of the cross-section (LAT), and LAT/AP ratio. The hyoid bone position was evaluated using eight linear parameters and two angular parameters. Facial characteristics were evaluated using three linear parameters and three angular parameters. Most hyoid bone position parameters (especially the distance between the hyoid bone and hard palate) were significantly associated with most airway dimension parameters. Significant correlations were also observed between the different facial characteristic parameters and hyoid bone position parameters. Most airway dimension parameters showed significant correlations with linear facial parameters, but they displayed significant correlations with only a few angular facial parameters. These findings provide an understanding of the static relationship between the hyoid bone position and airway dimensions, which may serve as a reference for surgeons before orthodontic or orthognathic surgery.

Key words: correlation analysis; upper airway; hyoid bone position; Chinese adolescents; cone-beam computed tomography.

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The upper airway is a tube-shaped structure that plays an important role in respiration and deglutition.[1] Anatomical anomalies of the upper airway, such as micrognathia, retrognathia, hyperdivergent growth patterns, reduced cranial base length, and steep mandibular plane angles, may lead to a narrow airway space, small volume, and even obstructive sleep apnoea.[2–4] The hyoid bone is the only bone that is not articulated to any other bone in the body, and is connected to the pharynx, mandible, and cranium through muscles and ligaments; this is necessary for talking, chewing, swallowing, and airway patency.[5]

Orthognathic surgery, as performed nowadays, can alter the pharyngeal airway dimension, and this is an interesting topic for orthodontists.[6,7] Mandibular setback surgery can narrow the airway[8,9] and cause a significant posterior movement of the hyoid bone.[10] Mandibular advancement surgery can increase the airway space volume and thus significantly widen the narrower sites.[4,11] Certain functional orthopaedic treatments have also been shown to change the pharyngeal airway dimensions and hyoid bone position in teenagers.[12] However, other functional orthopaedic treatments such as rapid maxillary expansion and modified bionator treatment are believed to have no influence on the pharyngeal airway and hyoid bone position.[10,13] Furthermore, the hyoid bone will move posteriorly and the airway dimension will become smaller or narrower in the case of the mandibular bone being moved backwards. Therefore, the correlations between airway dimensions and hyoid bone position should be considered carefully during orthodontic diagnosis and treatment.[8,14] However, an analysis of the correlation between upper airway dimensions and the hyoid bone position in teenagers with normal maxillofacial characteristics has not yet been reported.

Cephalometric analysis has been used previously to study the correlations between airway and hyoid bone positions.[15] However, lateral cephalograms only display the sagittal plane, while related information on axial width, cross-sectional area, and volume are missing when assessing the morphology of the upper airway. Cone beam computed tomography (CBCT) provides a reliable and accurate method to analyze the airway dimensions,[16,17] soft tissue, and surrounding airway space.[18,19] As reported previously, the CBCT scan obtained before orthodontic diagnosis and treatment can help in gaining a clear clinical judgement of the upper airway space and hyoid bone position in patients.[20] Therefore, CBCT is a standard method adopted in otolaryngology for early diagnosis and evaluation, and assessment of the upper airway by CBCT has become a necessary step before orthodontic or orthognathic surgery.[14,21] However, CBCT scans have rarely been used to investigate the relationships between the upper airway and hyoid bone position in healthy teenagers.

In this study, the correlations between upper airway dimensions and hyoid bone position were investigated in Chinese adolescents based on CBCT images, with the goal of highlighting the need to pay greater attention to the adverse effects of orthodontic or orthognathic treatments, and also to provide more references for appropriate treatment planning.

Materials and methods

Subjects

CBCT images were obtained from the CBCT image library of the Stomatology Hospital of Shandong University. Only images of patients of Han Chinese ethnicity, aged 6–18 years, taken between December 2010 and December 2012, were included. Strict inclusion criteria were applied while examining the medical history and CBCT images of the study subjects.

With regard to the CBCT images, only those for subjects meeting the following criteria were included: (1) clinically symmetric; (2) class I molar relationship, normal overjet and overbite; (3) no discrepancy in centric relation/centric occlusion; (4) no history of previous orthodontic treatment; (5) reasonably aligned upper and lower incisors without severe crowding; (6) no missing permanent teeth; (7) acceptable oral hygiene without obvious periodontal disease.[22] CBCT images in which the airway structure was not seen clearly or was not complete were excluded, as well as airways containing artefacts.[23]

In terms of the medical history, the selection criteria included no history of any craniofacial surgery or anomaly, no congenital anomalies (such as cleft lip and palate), no dysfunction of the masticatory system, no respiratory pathology or pharyngeal pathology (such as adenoid hypertrophy, tonsillitis and adenoidectomy, or history of tonsillectomy), no history of breathing problems, and no mouth breathing habit, complaint of airway restriction, nasal obstruction, snoring, or obstructive sleep apnoea. This study was approved by the necessary research ethics committee. Finally, 254 CBCT images from 119 males and 135 females were included in this study.

CBCT process

For CBCT scanning, each patient was seated in an upright position and asked to keep their jaws in maximum intercuspation, with the lips and tongue in a resting position. The Frankfort horizontal plane (FH plane) of the patients was kept parallel to the floor. Patients were instructed to breathe normally through the nose, avoiding swallowing and moving their head or tongue during the scanning process. All of the images were acquired using a Galileos CBCT scanner (Sirona, Bensheim, Germany) at 85 kV, 7 mA, and 14 s per rotation (resolution accuracy <0.15 mm). CBCT images were then saved as DICOM (digital imaging and communications in medicine) files.

Segmentation and measurement

The DICOM files were imported into Materialism's interactive medical image control system (MIMICS) (v.16.01; Materialise, Leuven, Belgium) to visualize the images in the axial, coronal, and sagittal planes by volume-rendering.

Once the DICOM files were imported, the three-dimensional (3D) reconstruction of the patient's head was oriented so that the FH plane was parallel to the axial plane and the midsagittal plane was oriented to the subject's midline.[11] The patient's midsagittal plane was defined as a vertical plane passing through both the anterior nasal spine (ANS) and the posterior midpoint of the spine (centrum) (Fig. 1A). Thirteen landmarks were labelled in the midsagittal view: sella (S), nasion (N), basion (Ba), deepest anterior point in the concavity of the upper labial alveolar process (A), deepest anterior point in the concavity of the lower labial alveolar process (B), menton (Me), anterior nasal spine (ANS), posterior nasal spine (PNS), the tip of uvula (UT), the base of epiglottis (EB), the highest point of hyoid bone (H), the most antero-inferior point on the corpus of the third cervical vertebra (C3), and the roof of the nasopharynx (Roof) (Fig. 1B). The hyoid bone position was evaluated using eight linear parameters C3–Me, C3–H, H–EB, H–PNS, H–Me, H–X, H–Y, and H–(C3–Me), as well as two angular parameters, H–S–Ba and H–N–S. Facial characteristics were evaluated using three linear parameters N–Me, N–ANS, and ANS–Me, as well