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Three-dimensional analysis of pharyngeal airway morphology in Japanese female adolescents

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ABSTRACT

Purpose: This cross-sectional study evaluated the three-dimensional craniofacial skeletal and pharyngeal airway morphology and the changes associated with skeletal maturation in Japanese female adolescents.

Materials and methods: The subjects were examined by cone-beam computed tomography and divided into two groups according to the stage of cervical vertebral maturation (adolescent group: 34 subjects, cervical stages 2 and 3, mean age 11.15±0.86 years; and late-adolescent group: 27 subjects, cervical stages 4 and 5, mean age 14.23±1.13 years). The size of the craniofacial skeleton and pharyngeal airway in each group were measured. Statistical differences between the two groups were determined using Student's *t*-test. Pearson's correlation coefficient was used to determine the relationships between the skeletal and pharyngeal variables in each group.

Results: The skeletal and pharyngeal airway parameters were significantly larger in the late-adolescent group than in the adolescent group. In the adolescent group, the anteroposterior position of the maxilla and mandible was significantly positively correlated with the volume of the nasopharyngeal airway ($P<0.05$). The mandibular size was significantly positively correlated with the oropharyngeal length and volume ($P<0.01$). In the late-adolescent group, we did not find any correlations between skeletal size or position and the volume of the pharyngeal airway during the adolescent period.

Conclusions: The nature of the relationship between skeletal morphology and pharyngeal airway volume seems to change from adolescence to late adolescence.

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1. Introduction

Physiological functions in the oromaxillofacial region, such as breathing, mastication, swallowing, and speech, are some of the most important functions supporting human life and social activities. It has been suggested that dentomaxillofacial growth and development are influenced by the condition of the airway [1–5]. Craniofacial morphology has a great influence on pharyngeal morphology: the pharynxes of children with Class III malocclusions were larger than those of children with Class I malocclusions, and the pharynxes of patients with Class II malocclusions were narrower than those of patients with Class I malocclusions [6]. Therefore, it is recommended that orthodontists acquire sufficient information about airway morphology in relation to pharyngeal function and related diseases for accurate clinical diagnosis of orthodontic treatment during adolescence.

Evaluations of the airway, soft tissue, and craniofacial morphology have been based mainly on two-dimensional (2D) images such as lateral cephalograms, from which it is difficult to precisely identify the three-dimensional (3D) structure due to limitations such as superimposition of anatomical structures and differential magnification between the left and right sides. In recent years, cone-beam computed tomography (CBCT) has become more widely used than conventional computed tomography (CT) in dental practice [7–11]. Compared with conventional CT, CBCT costs less, needs lower radiation exposure, and requires a shorter scanning time with a higher resolution [12–15]. As a result, 3D morphological analysis, including volumetric measurement in the craniofacial region, has become available. However, few studies have demonstrated the 3D morphological relationships between the craniofacial skeleton and the pharyngeal airway in adolescents.

Individual skeletal maturation should be assessed based on physiological age because there are individual differences in the start, duration, and rate of the growth peak at puberty. Hand-wrist radiographs have been used routinely in orthodontics to assess skeletal maturation [16–18]; however, this requires an additional radiograph. Recently, the cervical vertebral maturation (CVM) method [19–24] has been used to assess skeletal maturation as an alternative to the hand-wrist method, and has been shown to provide a valid indicator of skeletal growth during puberty. Therefore, we used the CVM method described by Baccetti et al. [23] to assess individual skeletal maturation based on 2D sagittal CBCT images.

The purpose of this study was to quantify the relationship between craniofacial skeletal and pharyngeal airway morphology and the changes associated with skeletal maturation in Japanese female adolescents.

2. Materials and methods

The study enrolled adolescent Japanese girls (age range 10–16 years) who visited Kanomi Orthodontic and Pediatric Dental Clinic (Hyogo, Japan) for orthodontic treatment of malocclusion; all were examined using CBCT. Before the imaging, the patients' parents were fully informed of the purpose and risks of CT, and consent was obtained from them.

The subjects were divided into two groups based on the stage of CVM [16]: (1) the adolescent group included 34 patients with cervical stages 2 and 3 with an average age of 11.15 ±0.86 years; and (2) the late-adolescent group included 27 patients with cervical stages 4 and 5 with an average age of 14.23±1.13 years (Table 1). Because the volume of pharyngeal airway is influenced by head posture [25], the craniocervical inclinations of all subjects were examined. In the present study, the craniocervical inclinations (from 80° to 108°) was almost similar to the previous report [26], which was between 90° to 110°. Patients with the following conditions were excluded from the study: those with congenital anomalies or endocrine problems and facial or spinal abnormalities; a history of trauma in the dentomaxillofacial and neck region; a history of previous orthodontic treatment; a history of allergic rhinitis, clinical signs or symptoms, and complaints of nasal obstruction at the initial visit; low tongue posture without nasal obstruction; pharyngeal pathology such as adenoid and/or tonsil hypertrophy; or a history of adenoidectomy or tonsillectomy. The study protocol was reviewed and approved by the Ethics Committee of the Faculty of Dentistry, Kyushu University (22-172).

2.1. *Reconstruction of the 3D CBCT image*

In this study, CT images were obtained using the facial mode (field of view, 192.5 mm) of a CB MercuRay (Hitachi Medical, Japan). The device was set to 120 kV at 15 mA, and the scanning time was 9.6 s. Patients were seated in a chair with the Frankfort horizontal (FH) plane parallel to the floor. They were asked to refrain from head movement and from swallowing with centric occlusions, and to put their tongue in a relaxed position during the examination.

The acquired digital axial images were transferred in digital imaging and communications in medicine (DICOM) format directly from the CT scanner to a personal computer. The rendered volume data in a 512 × 512 matrix with a voxel size of 0.377 mm were reoriented as shown in Fig. 1 using volume-rendering software (VG Studio MAX 1.2, Nihon Visual Science, Tokyo): (1) the axial plane was parallel to the FH plane, which was defined by the right and left porions and the centers of the right and left orbitales; (2) the frontal plane was perpendicular to the FH plane, passing through the right and left porions; and (3) the sagittal plane was perpendicular to the FH and frontal planes, passing through the centers of the right and left orbitales. After defining the 3D spatial coordinate system, craniofacial skeletal (a cranium–maxilla complex, mandible, cervical vertebrae) and pharyngeal airway structures were

Table 1 – Sample characteristics.

	Adolescent group (CS 2 and 3)	Late-adolescent group (CS 4 and 5)
Subjects (n)	34	28
Age (y) (mean ± SD)	11.15 ± 0.86	14.23 ± 1.13

CS, cervical stage of the cervical vertebral maturation (CVM); SD, standard deviation.

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