Correlation between three-dimensional morphological changes of the hyoid bone with other skeletal maturation methods in adolescents

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Objective. The study compares growth changes of hyoid bone in cone-beam computed tomography (CBCT) with conventional skeletal maturation methods to examine their potential implications in the development of a three-dimensional method.

Study design. Subjects ($n = 62$, 11-17 years of age) were exposed to CBCT at a six-month interval (T1/T2/T3). Ten-hyoid distances were compared with age, hand wrist skeletal maturation index (SMI), and cervical vertebral maturation stage (CS).

Results. The length of greater cornua (GC) was most frequently, moderate to highly correlated with age (right: 0.57/0.53/0.58; left: 0.45/0.50/0.48), SMI (right: 0.52/0.40/0.45; left: 0.42 at T3), and CS (right: 0.52 at T1), followed by the length of the hyoid bone with age (right: 0.50/0.49/0.47; left: 0.44/0.47 at T1/T2), SMI (right: 0.45/0.41 at T1/T2), and CS (right: 0.48 at T1). The width of body of the hyoid (HB) width was correlated with age (0.43/0.44/0.44). The GC−HB gap was correlated with age (right: −0.41 at T3) and SMI (right: −0.42 at T1).

Conclusion. Peripubertal hyoid maturation did not yield sufficient diagnostic information for considerations in the development of a 3D-skeletal maturation method. (Oral Surg Oral Med Oral Pathol Oral Radiol 2013;116:511-517)

Numerous methods for the assessment of skeletal maturation are described in the literature[1-4] and the methods are based on two types of radiographs: hand-wrist radiographs and lateral cephalograms. Although not a gold standard, lateral cephalograms approach in the assessment of skeletal maturation is most often used and is supported by research in orthodontic treatment as this type of radiograph is routinely taken in practice and avoids unnecessary exposure to radiation.[5-10] Studies relating peripubertal growth and development of hand-wrist bones or cervical vertebrae with growth potential in the mandible created the foundation of knowledge, which is used to identify remaining growth potential of the mandible and determine the timing of treatments in adolescents who presents for orthodontic consultations.[11-13]

The expanding scope of cone-beam computed tomography (CBCT) in the dental profession has led to interests in the development of skeletal maturation methods for this new imaging modality.[14-18] In our previous study, the implications on the assessment of skeletal maturation when a lateral cephalogram approach is used to assess CBCT images were investigated.[19] The study concluded that the cervical vertebral maturation stages (CSs) determined from CBCT images were not only inconsistent with those based on lateral cephalograms but also the assessments of CBCT images were inconsistent among the examiners, warranting further studies on cervical vertebral maturation or on other potential maturational indicators in CBCT images.

The hyoid bone is an interesting avenue for consideration in the assessment of skeletal maturation. The bone lies between the base of the mandible and third cervical vertebrae. It is made up of six ossification centers, two for the hyoid body and one for each cornu, with subsequent synchondroses of cartilaginous joints followed by bony fusions.[20] Age- and gender-related morphological variations of hyoid bone have been the focuses for many researches in forensic science and legal medicine.[20-24] Some studies particularly investigated on the age of unilateral and bilateral fusion of the greater cornua (GC) and the body of the hyoid in females and males, as fused hyoid bone is more likely to fracture during manual strangulation.[20-22,24] The hyoid bone has also been established as one of the methods for the estimation of age past 25 years of life in

Statement of Clinical Relevance

Growth and developmental changes of the hyoid bone can potentially provide diagnostic information for determining skeletal maturity of adolescents. Development of 3D assessment method may prevent further radiation in adolescents who have been exposed to CBCT scanner.

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skeletal remains.[21] Many of these studies included subjects between the third to seventh decade of life and therefore, there is insufficient information on the maturation of hyoid bone in adolescents.

The present study will determine morphological three-dimensional (3D) changes in the hyoid bone based on CBCT images of adolescents and correlate them with other skeletal maturation methods to survey their potential implications in the development of 3D methods for maturation analysis.

MATERIALS AND METHODS

The University of Alberta Human Ethics Research Board approved this research. DICOM data used in the study were available from another study, a randomized clinical trial examining short- and long-term skeletal and dental effects of bone-anchored maxillary expansion and traditional rapid maxillary expansion.[25] Sixty-two subjects between 11 and 17 years of age (43 females; 19 males) were recruited from the U of A Orthodontic Clinic patient pool over an 18-month period. Patients with history of normal development and no syndromes were recruited for the study. Ethnicity was not considered in the study. Subjects − organized into two treatment groups and one control group − were exposed to NewTom 3G (Aperio Services, Verona, Italy) at 110 kV, 6.19 mAs, and 8-mm aluminum filtration three times (T1/T2/T3) approximately at 6-month intervals, which represented important time points during the clinical trial − baseline, after removal of the appliance (6 months), and just before fixed bonding (12 months). The standardization of patient positioning was ensured using the following protocol. Patients are in supine position with a vertical laser at midline to the face. Patient was positioned so that a second laser has its pinpoint anterior to tragus on the right side. Images were converted to DICOM format by using the NewTom software to a voxel size of 0.25 mm. Four CBCT images were disregarded because they did not contain all pertinent parts of the hyoid bone. Final sample size was 182.

A statistician generated a random sequence. An examiner who was not involved in patient case analyzed CBCT images by reconstructing DICOM data into volumetric images using Avizo 6 Visual Standard (Visualization Sciences Group, USA). The examiner was blinded to patient age, CS, SMI score but knew the patient's name and the date of the record taken. Landmarks were positioned to identify the anterior and posterior ends of the GC in coronal slices and the lateral ends of the body of the hyoid in sagittal slices (Table I and Figures 1 and 2). Anterior, posterior (of the lower half), superior, and inferior points on the body of the hyoid were determined in mid-sagittal plane. The plane was approximated by an orthoslice in yz plane, which divided the body of the hyoid into most symmetrical and equal halves in both the axial and coronal view. Linear distances between various pairs of landmarks were computed for analysis. For optimal viewing condition, the width of contrast was set at maximum and center of contrast was manipulated as needed.

Various pairs of landmark coordinates were used to make ten linear measurements on the hyoid bone: lengths of the GC; width, depth, and height of the body of the hyoid in the mid-sagittal plane; widths of the gaps between the GC and the body of the hyoid; and width and lengths of the hyoid bone (Table II and Figure 3). Subjects' hand-wrist skeletal maturation index (SMI) and CS at the three time points were determined in a previous study,[26] and followed methods proposed by Fishman[27] and Baccetti et al.[11] respectively. Ten distances in the hyoid bone were compared with subjects' chronological age, SMI, or CS at the three time points using Pearson's correlation. Spearman's nonparametric correlation coefficient was calculated for SMI and CS. Correlation coefficients ≥ 0.5 or ≤ -0.5 was considered high in the study. Lastly, the mean differences in distances during the T1-T3 period − which ranged between 9.75 and 16.50 months − was computed by age groups.

For intra-examiner reliability, the principal examiner completed three trials of landmark placements on ten randomly selected CBCT files over 3 weeks. To ensure the examiner's consistency with other operators, a second examiner completed a trial of CBCT files and the landmark coordinates was compared to the first trial done by the principle examiner. Intraclass correlation coefficients (ICC) were computed for each x-, y-, and z-coordinate. Furthermore, in the case of inter-examiner reliability, ICC was computed for each landmark.

RESULTS

Examiner reliability test results were excellent. Intra-examiner ICC was 0.999, 0.999, and 0.998 for x-, y-, and z-coordinates respectively. In inter-examiner reliability, ICC was computed for 38 landmarks and the lowest ICC for each coordinate are considered as the test for reliability. Lowest ICC was 0.978, 0.997, and 0.990.

Strength of the association between ten linear measurements of the hyoid bone and different skeletal maturation methods − chronological age, SMI, and CS − for time points are reported in Table III. Most significant association was observed between anteroposterior length of the greater cornu on right and age, SMI and CS at T1 (0.57, 0.52, and 0.52). This distance remains highly correlated with age at T2 and T3 (0.53 and 0.58). The overall anteroposterior length of the hyoid bone on right is highly correlated with age as well at T1 (0.50). Mild correlation ($|0.4| \leq x \leq |0.5|$)