ORIGINAL ARTICLE

Quantitative analysis of the maxilla and the mandible in hyper- and hypodivergent skeletal class II pattern

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Structured Abstract
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Objectives – To examine the volumetric (size) difference in the maxilla and the mandible of hyper- and hypodivergent skeletal patterns in Angle class II malocclusion.
Design – Descriptive retrospective study. The hypothesis is that a hypodivergent mandible has a larger size than a hyperdivergent mandible.
Setting and Sample Population – Using cone-beam computed tomography, 20 subjects with Angle class II malocclusion were classified into two groups; 10 of 20 subjects formed a hyperdivergent group while the rest formed a hypodivergent group.
Material and methods – Cone-beam computed tomography images were obtained and processed and 3D volume data was measured by one clinician. Dahlberg's technique was used to assess the measurement error and significant difference was set at $p < 0.05$.
Results – No significant differences were found between the volumes of the maxilla and mandible in both groups. Differences were observed in the ratio of mandibular/maxillary volumes. The hypodivergent group had a significantly larger ($p = 0.014$) ratio than the hyperdivergent group.
Conclusions – Maxillary and mandibular volumes differ between hyper- and hypodivergent skeletal patterns.

Key words: Angle class II; cone-beam computed tomography; hyperdivergent; hypodivergent; malocclusion

Introduction

Conventional two-dimensional (2D) cephalometric analysis, as the method of linear and angle measurements, has been used to study horizontal (transverse), sagittal (anterior–posterior) and vertical problems in growth and abnormalities of skeletal morphology. However, 2D analysis does not provide any quantitative information of the maxillary and mandibular volume and size. Recently, cone-beam computed tomography (CBCT) systems have been developed and applied to the fields of the maxillofacial complex (1–3). This cone-beam imaging gives us three dimensional (3D) data not only for studying growth modification, but also evaluating

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orthodontic–orthopaedic treatment results in orthodontics. 3D data of shape, size and volume can describe the orthopaedic treatment effects of protraction of the maxilla, retraction of the mandible and rapid maxillary expansion in 3D. A study in rabbits reports that chin cap appliance can expand the width of the mandible, and 3D analysis is valuable in understanding all the changes (4). But so far there is no clinical data that chin cap force expands the width of mandible. CBCT also presents accurate imaging of temporomandibular joint (5).

The purpose of this pilot study was to examine volumetric differences between hyperdivergent and hypodivergent skeletal class II patterns in patients with Angle class II malocclusion.

Materials and methods

The samples consisted of the records of 20 adult females who fitted into Angle class II malocclusion selected randomly from the archive of a private orthodontic office in Kyoto, Japan. The inclusion criteria were: 1) no history of previous orthodontic treatment; 2) complete permanent dentition present; 3) bilaterally half or greater unit class II cuspid and molar relationships in both groups. Written consent was taken from all participants.

Each patient had CBCT, lateral and frontal cephalometric radiographs as part of the pretreatment records. These patients were classified into two groups; 10 of 20 subjects formed the hyperdivergent group (mean Frankfort Mandibular plane Angle, or FMA, 38.3°) while the remaining 10 formed the hypodivergent group (mean FMA, 19.8°). The average FMA in a normal, Japanese adult is 28.8° (6).

Imaging was performed using the CB MercuRay™ (Hitachi Medico Corporation, Tokyo, Japan). The device was operated at 15 mA and 100 kV with a single scan time of 10 s. Each field of view mode was 12 inches. Upon completion, the image was processed with CyberMed's CB Works™ software (CB Works 1.0; CyberMed Inc., Seoul, Korea). Threshold was set for the most distinguished image of maxilla and mandible. 3D image was obtained by rendering a 3D volume. The reference measurement was the maxillary volume including the lower side of the palatal plane (an anatomical Pns-Ans line) that does not contain tooth crowns. The volume of the mandible was measured without tooth crowns, including the condyle. The boundaries of alveolar bone and tooth crown were drawn by free hand of the clinician (SK) (Fig. 1). This volume method of the maxilla and the mandible was originally developed jointly by the corresponding author (TD) and the clinician who did the assessments.

The scheme of the sagittal views for setting the boundaries of the maxillary volume is shown (Fig. 2A, B).

Although CBCT images were not made in a standardized position, there are reference points when a CBCT is taken: 1) at first, the patient's head is fixed by a head holder; 2) the lateral line of light of the floodlight

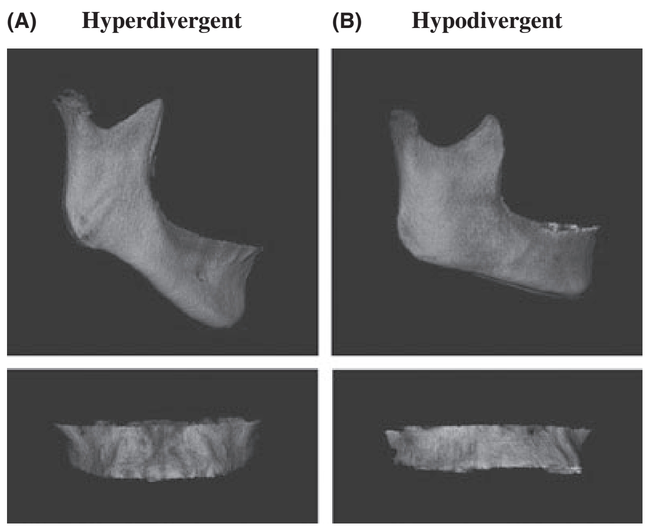

Fig. 1. Cone beam 3D image of maxilla and mandible without crown of teeth. (A) Hyperdivergent subject. (B) Hypodivergent subject.

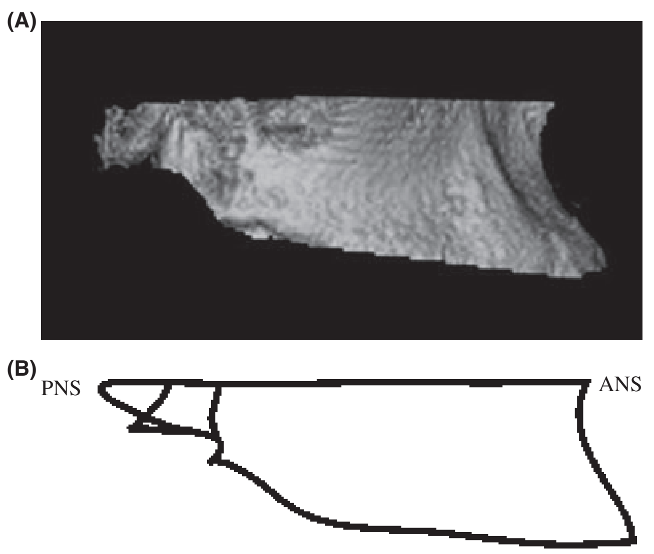

Fig. 2. (A) Sagittal view of the maxilla volume. (B) Drawing of the maxilla volume setting.

projector is set parallel to the Frankfurt plane; 3) the frontal line of light is set parallel to the orbital line and the perpendicular line of light is perpendicular to the midline of the face.

Statistical analysis

Statistical analysis was performed using software SPSS 15.0 (SPSS Inc., Chicago, IL, USA). Age-adjusted linear regression was used to compare the measurements of the hyper- and hypodivergent groups and $p < 0.05$ was assumed to be significant. To verify the accuracy of the 3D measurements, the maxillary and mandibular volumes of five randomly chosen subjects were measured twice and Dahlberg's technique was used to assess the error.

Results

The measurement error is shown in Table 1. Descriptive statistics for age, maxillary and mandibular volume and the mandible/maxilla ratio are shown in Table 2. There were no statistical significant differences for the mandibular or maxillary volumes between the two groups. Differences were observed in the ratio of mandibular/maxillary volumes. The hypodivergent group had a significantly higher ($p = 0.014$) ratio than that of the hyperdivergent group.

Discussion

Conventional cephalometric analysis states that the hyperdivergent skeletal pattern in Angle class II malocclusions has the characteristics of a retrusive and backward rotated mandible, protrusive maxilla and large lower facial height. The hyperdivergent skeletal pattern presents poor muscle activity with lower maximum bite force than the hypodivergent pattern in both children and adults (7, 8). Both the quantity and biological quality of the masseter muscles is different in bite groups with different vertical dimensions. Open bites, similar to the hyperdivergent type, have an increased number of type I fibres and deep bites, similar to hypodivergent type, have an increased number of type II fibres (9).

The relationship between human jaw muscles and craniofacial morphology has been studied previously (10–12). Gionhaku and Lowe (13) reported that subjects with large masseter and medial pterygoid muscle volumes had flat mandibular and occlusal planes, and a small gonial angle, which are characteristic features of hypodivergent patients. As the skeletal divergence increases, muscle metabolic activity decreased. Muscles in the hypodivergent pattern have a higher resting metabolic activity, keep bone under more tension and grow in a more horizontal direction (14). Hyperdivergent subjects may have a 40% higher temporal activity, which could result from an unstable position of the mandibular movement and a weaker biting force than a hypodivergent subject (15). There was a statistically significant greater distraction (displacement) of the condyle in the hyperdivergent subjects than in the hypodivergent subjects (16).

Table 1. **Measurement error (mm^3)**

	Hyperdivergent	Hypodivergent
Maxilla volume (mm^3)	462.96	290.32
Mandibular volume (mm^3)	455.83	462.96

Table 2. **The characteristics of the hypo- and hyperdivergent groups and volumes of maxilla and mandible (mm^3) and mandible/maxilla ratio**

	Hyperdivergent	Hypodivergent	*p*-value
Age (years)			
Mean (SD)	22.3 (5.3)	19.6 (5.7)	0.293
Range	16.3–29.6	13.5–31.6	
Median	22.5	17.2	
Maxilla volume (mm^3)			
Mean (SD)	15618.8 (2067.2)	13860.0 (2038.9)	0.165*
Range	11922.4–19753.0	11143.7–19684.6	
Median	15292.1	13463.2	
Mandibular volume (mm^3)			
Mean (SD)	44416.6 (6872.1)	48062.8 (8575.7)	0.253*
Range	35123.1–59391.9	31482.4–63036.8	
Median	44265.8	47689.1	
Mandible/maxilla (ratio)			
Mean (SD)	2.84 (0.30)	3.47 (0.44)	0.014*
Range	2.36–3.57	2.73–4.34	
Median	2.89	3.54	

*Age-adjusted *p*-value.

In a previous study, the difference in the volumes (size) of the maxilla and mandible, and its ratios in skeletal classes I, II and III malocclusion was determined (17). The results indicated that skeletal class III subjects had a significantly higher maxilla/mandible ratio compared to class II subjects, which means the largest mandible and smallest maxilla were found in class III subjects. There was an apparent trend ($p = 0.089$) in which class III subjects may have a significantly larger mandibular volume.

The aim of this study was to compare the volumes of the maxilla and the mandible in skeletal hyper- and hypodivergent skeletal class II in Angle class II malocclusion subjects using CBCT. Dental CBCT could be less powerful than multislice CT scanning. The CBCT images may not show the alveolar bone or cartilaginous structures with precision. In spite of this disadvantage, it can be used for analyses of volume and shape. It can also compare the distance between reference points in 3D between the right and left side.

A study of the relationship between facial types (hypo- vs. hyperdivergent pattern) and bone thickness revealed that bone morphology is related to masticatory function and that face types are associated with cortical bone thickness in the body of the mandible and the buccal inclination of the molars (18). The body of the mandible in a short-face (hypodivergent) pattern has a thicker cortical bone than that of a long-face. Decreased bite force, muscle function and biological efficiency in skeletal hyperdivergent class II malocclusion could lead to smaller volumes of the mandible than those of hypodivergent subjects. However, in the present study, the hyper- and hypodivergent subjects showed no significant difference in the maxillary and mandibular volumes. However, there was a difference in the ratio of mandibular/maxillary volumes, because bone size varies between individuals. The volumetric ratio of mandible and maxilla may be used in future as an indicator for oro-facial abnormalities.

It can be noted that the effect size resulting from the use of ratio might be higher than that from the use of either maxilla or the mandible alone (in the comparisons). This may have resulted in the statistical significance of the comparison using mandibular/maxillary volumes and not the others. Larger sample size may have resulted in statistical significance in the other comparisons.

Conclusions

No significant differences in the volumes (size) of the maxilla and mandible in hyper- and hypodivergent groups were observed. A significant difference in the ratio of mandibular and maxillary volumes was found.

Clinical relevance

Traditionally, cephalograms have been used to provide clinical information for diagnostic and treatment purposes in orthodontics. During orthodontic treatment orthopaedic forces – retraction or protraction of mandible and maxilla-induce 3D dento-maxillofacial changes. More advanced methods, such as CBCT and 3D analysis could provide more precise data regarding skeletal changes using precise registration of landmarks and superimposition of skeletal components than those of traditional cephalograms in orthodontics.

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