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Orthodontic evaluation by cluster and factor analyses from 2D frontal and lateral profilograms derived from 3D CBCT images

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ABSTRACT

Background: Two-dimensional lateral and frontal profilograms reconstructed out of cone-beam computed tomography (CBCT) images were analyzed by cluster analysis with 26 variables of angular and dimensional proportions. Quadrilateral polygons were drawn from means of variables for each cluster, as prototypes of profilograms, to find subgroups by factor analysis, to find relationship of selected variables, and to find significant differences of airway volumes among clusters.

Methods: A total of 301 adults, 18 to 56 years (160 men and 141 women) were selected retrospectively. Two-Step-Cluster (TSC) analysis was applied to find clusters of variables and categorized as M1, M2, F1, and F2. Factor analysis was performed to have subgroups of 26 variables. Prototypes of profilograms were superimposed to explore relationship of selected variables. Significant differences in airway volumes were analyzed by 1-way analysis of variance.

Results: The frontal profilograms revealed asymmetry. The lateral profilograms of M2 cluster revealed a downward and backward growth pattern, whereas M1 revealed forward growth pattern. All clusters revealed nasal width to be half that of palatal width, and one-third of the mandibular width. The palate distance was two-thirds of the mandibular width and length. The posterior vertical height was half of the anterior.

Conclusions: Orthodontic evaluation could be approached by mapping any profilogram to our prototypes. M1 had skeletal Class 3 deep bite. M2 showed Class 2 open bite. Women revealed similar forward growth pattern, whereas male clusters distinguished divergence or convergence clearly.

1. Introduction

Cone-beam computed tomography (CBCT) forms an important tool for diagnosis when patients are required to investigate for their missing, malpositioned, or embedded teeth. Nowadays, dental CT or CBCT [1,2] is commonly used for more certainty in treatment planning involving dentofacial structures. The advantage of CBCT over 2-dimensional (2D) X-ray imaging is that it provides reconstruction of 2D images without further exposure. Recently, due to resurgence in the diagnosis of obstructive sleep apnea (OSA), airway morphology and facial growth have become areas of interest in orthodontics [3]. The patients' quality of life declines because of lack of sleep. Orthodontic patients, both children and adults, may experience lack of sleep due to inadequate breathing with the underlying OSA. Orthodontists, if willing to include airway analysis and volume assessment during their clinical examination, as well as analyzing investigative aids, can identify these patients and refer them for further investigation by sleep specialists [4].

The principle of cluster analysis is that from the original pooled data of the whole sample, all variables would be analytically grouped by a 2-step cluster (TSC) method repeatedly, until the statistical program reaches a final decision. To apply cluster analysis of angular, linear, and dimensional proportions to be mentioned as "variables" [5], 2D images were reconstructed out of 3D CBCT images in the lateral and the frontal views. The variables will be analyzed by cluster analysis to yield cluster groups. Single and double quadrilateral polygons, known as "profilogram," will be drawn from mean values of variables for each cluster in the lateral and the frontal views, respectively, and will be called as prototypes. After the cluster groups of variables are distinguished, factor analysis would be applied to all variables, to reduce and categorize them to have some group representatives. In this way, we may not need to measure or interpret all the data. To our knowledge, no published literature exists in which proportions were the focus in analyzing

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airway characteristics in orthodontics, rather than the horizontal and vertical characters of skeletal discrepancy.

The following were the objectives of this study:

1. To propose another way for cephalometric evaluation without numeric data of subjects by creating the profilograms obtained from cluster analysis of cephalometric variables in men and women, and to assess whether matching any patient with our prototype profilograms would be possible.
2. To apply factor analysis to all variables for possible reduction to create representative images.
3. To find the statistically significant difference, if any, among selected variables in the representatives obtained, and its relationship with clusters by 1-way analysis of variance (ANOVA).
4. To measure the airway volumes and to find the statistically significant difference, if any, between mean airway volumes among clusters by 1-way ANOVA.

2. Materials and methods

The Human Research Ethics Committee approved this study with the code HREC-DCU 2016-066.

2.1. PP-CV2 measurement

Before airway measurement by CBCT, proper head posture must be assessed with the value of the angle between the Sella-Nasion (SN) plane and the second cervical vertebra (CV2) to be 90 to 110 degrees, as suggested by various studies [6–8]. This angle is called SN-CV2. However, CBCT obtained with a smaller field of view (FOV) and not large enough to cover up to SN plane and were not amenable to visualize or measure SN-CV2 angle. Previous studies [9,10] used the palatal plane (PP) as a reference line, because PP showed less or no change compared with the occlusal plane (OP) or the mandibular plane (MP), which usually varies with growth. This study proposes the anterior nasal spine–posterior nasal spine (ANS-PNS) to CV2 (PP-CV2) angle as the new palato-cervical measurement, as shown in Figure 1. To obtain a range of PP-CV2 measurements, we needed to select patients with regular lateral cephalograms (Kodak 8000C or 9000C; Caresteam, Rochester, NY), taken using the usual standardized method (60–90 kVp, 2–12 mA, 0.1–3.2 seconds). The regular 2D x-ray lateral cephalograms from the patients were collected and subjected to measurement of the ANB (A point, nasion, B point) angle (2 to 6 degrees) and SN to mandibular plane (SNMP) angle (28–40 degrees) to make sure that these belonged to those patients with normal horizontal and vertical skeletal patterns. We obtained normal range of PP-CV2 angle from these images in which SN-CV2 were visible and could be considered as within the accepted range (Fig. 1). The PP-CV2 ranges of these patients were between 76.23 and 104.15 degrees, measured using Image J version 1.47 (National Institutes of Health, Bethesda, MD).

2.2. CBCT selection, clustering, and profilogram

CBCT images were obtained from the existing database (secured between 2007 and 2015). The inclusion criteria were as follows: adult patients with age not less than 18 years; no history of trauma, injury, or surgery of the dentofacial structures; no presence of hemifacial microsomia or other facial deformity syndromes; no obvious signs or symptoms of OSA and no obvious adenoid pathology [3,4,11]. The data were collected and stored as per standard guidelines in the dental profession [12] and the Declaration of Helsinki [13]. CBCT images were taken using a 3DX Accuitomo 170 (J. Morita, Kyoto, Japan) at 60 to 90 kVp, 1 to 10 mA, 17.5-second scanning time, voxel size 0.25 mm, and a CB MercuRay (Hitachi Medical Systems America, Twinsburg, OH) at 120 kVp, 15 mA, and 9.8-second scanning time, voxel size 0.29 mm. Out of these images, 2D cephalometric images were rendered using the Romexis (Planmeca, Helsinki, Finland) program and brought to Image J to measure PP-CV2, to select those with PP-CV2 angle in the accepted range. The purpose of this step was to eliminate the subjects of unaccepted head position out of this study and to include CBCT images with smaller FOV, in which SN-CV2 was not visible, to be included in this study. Finally, 301 adults, age ranging from 18 to 56 years (160 men and 141 women) were included. Twenty-six variables were shortlisted from 2D images derived from CBCT (Table 1) in the sagittal and the coronal planes, as shown in Figure 2.

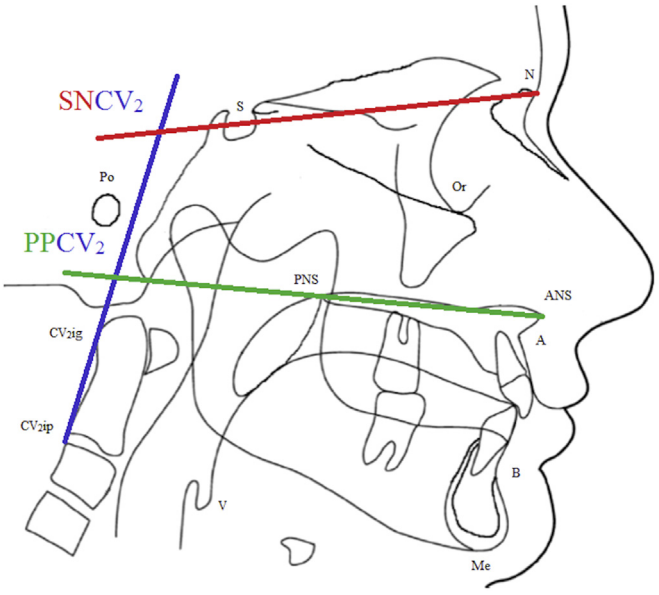

Fig. 1. Landmarks of lateral structures are as follows:

- Anterior Nasal Spine (ANS): Most anterior point of the nasal floor
- Posterior Nasal Spine (PNS): Most posterior point on the contour of the bony palate
- Menton (Me): Lowermost point on the contour of the mandibular symphysis
- Gonion (GO): Located by bisecting the angle of the posterior ramal plane and the mandibular plane
- Cervical vertebra 2 (CV_2) was used for location of the craniocervical measurement as the Sella-Nasion and CV_2 (SNCV2) angle
- CV_2ig: Most supero-posterior point on the odontoid process of CV_2
- CV_2ip: Most infero-posterior point on the odontoid process of CV_2

Table 1
Details of 26 linear, angular, and proportional measurements as "variables"

View	Measurement		
	Linear	Angular	Proportional
Frontal	**N_1, P_1, M_1** **V_1, V_2, V_3, V_4**	**A_5, A_6, A_7, A_8**	**N_1 / P_1** **P_1 / M_1** **N_1 / M_1**
Lateral	P_2, P_3, M_4	A_1, A_2, A_3, A_4	P_2 / M_4

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