Comparative study of cephalometric measurements using 3 imaging modalities

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ABSTRACT

Background. The authors conducted a study to compare 2-dimensional (2D) lateral cephalometric radiography (LCR), 2D cone-beam computer tomographic (CBCT)–generated cephalogram and 3-dimensional (3D) CBCT for assessing cephalometric measurements.

Methods. The authors took 2D LCR, 2D CBCT-generated cephalogram, and 3D CBCT images involving 60 participants. They obtained 11 angular and 11 linear measurements for all images. They used 1-way analysis of variance and the Fisher least significant difference test for statistical comparisons. The authors used Pearson correlation and Pearson χ^2 test to assess the relationship of these imaging modalities for vertical cephalometric analyses.

Results. Significant differences existed between the 2D cephalograms (LCR and CBCT-generated cephalogram) and the 3D CBCT in 2 angular measurements (maxillary first incisor-nasion (N) point A [A] and mandibular first incisor-N point B (B) ($P = .027$ and $P < .001$, respectively) and 5 linear measurements (N menton[Me]/sella gonion [Go], condylion [Co]A, Co gnathion, Go-Me and anterior nasal spine-posterior nasal spine) ($P < .004$). These measurement values with significant differences were generally greater (approximately 5° for angular measurements and 10 millimeters for linear measurements) on the 3D CBCT scans than on the 2D cephalograms. No significant difference was found between the 2 2D cephalograms ($P > .164$). No significant difference was found among the 3 imaging modalities for the vertical cephalometric analyses ($P > .466$).

Conclusions. Significant differences existed between the 2D cephalograms (LCR and CBCT-generated cephalogram) and the 3D CBCT scans in 2 angular and 5 linear measurements. The 2 2D cephalograms were similar for cephalometric measurements. The 3 imaging modalities had no significant difference for the vertical cephalometric analyses. CBCT might not add value for every orthodontic situation.

Practical Implications. These results find the values of cephalometric measurements on 3D CBCT scans may be greater than on the conventional LCR for some parameters. The 2D CBCT-generated cephalogram could be an alternative to the conventional LCR for patients whose large-field-of-view CBCT images are already available.

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Cephalometry has been used for decades to measure and assess craniofacial skeletal, dental, and soft-tissue relationships in orthodontics. Conventional 2-dimensional (2D) lateral cephalometric radiography (LCR), however, has a number of limitations, including image magnification, errors in designating the measuring-point, and rotation of the head.[1-3] The 3-dimensional (3D) cone-beam computed tomography (CBCT) has advantages to overcome the challenges of superimposition and magnification, providing greater precision for diagnosis and analysis than the traditional 2D LCR.[2] In addition, the 3D CBCT scan obtained from a patient can also be used to generate a 2D cephalogram as an alternative to traditional LCR, minimizing further radiation exposure and financial cost.[4]

Several studies have compared the conventional 2D LCR and 2D CBCT-generated cephalogram both in vivo and in vitro; however, no consistent conclusions were obtained among these studies.[5-10] Some studies showed that the measurement results for 2D CBCT-generated cephalograms did not clinically differ from those on the 2D LCR[3,5,6]; other studies have reported a statistically significant difference between these 2 2D cephalograms.[7-9] Some researchers compared 3D cephalograms with 2D LCR in white and South Korean populations,[10-15] The limitations of those studies made it difficult to generalize their results to clinical orthodontics, as some studies were carried out on human skulls in vitro,[10,11] some studies only assessed a limited number of measurements,[10,14] some investigators used the reconstructed spiral computer tomography (CT), which involved higher cost and radiation exposure in comparison with the CBCT,[12] and the sample sizes of those studies were generally small (8-10 participants)[11,13,14] To date, no study has compared 2D LCR, 2D CBCT-generated cephalograms and 3D CBCT scans in vivo for any population including Chinese.

Both 2D and 3D cephalograms can be used to assess the sagittal and vertical relationships of the maxilla and mandible, which play critical roles in achieving facial balance during orthodontic treatments.[16,17] Studies on sagittal intermaxillary relationships using 3D CBCT report useful information[18,19]; however, the analysis of the vertical intermaxillary relationship using 3D CBCT is still poorly understood. Furthermore, few studies have evaluated whether the classification of patients, according to the vertical cephalometric analyses on 2D cephalogram, can be extrapolated to 3D cephalometry.

We aimed to compare 2D LCR, 2D CBCT-generated cephalograms, and 3D CBCT scans for assessing angular and linear cephalometric measurements and to determine whether the classification of patients according to vertical cephalometric analyses based on 2D cephalograms can be extrapolated to 3D CBCT cephalometry.

METHODS

We conducted a study at the Nanjing Stomatological Hospital Orthodontic Department, Nanjing, China. We enrolled 60 patients (21 male and 39 female, mean age 21.3 years) before orthodontic treatments began in the study between January 2014 and December 2015. We used CBCT as part of our examination for the following reasons: impacted teeth (for example, canines or third molars), supernumerary teeth, temporomandibular joint disorders, and borderline (extraction versus nonextraction) cases, or camouflaged cases for which alveolar conditions required procedures before treatment planning. Patients gave us informed consent which included permitting our use of their data for research purposes. The study was approved by and in compliance with the Ethical Standards of Nanjing Stomatological Hospital 2012.

The inclusion criteria were both LCR and CBCT were obtained on the same day with good quality, no orthodontic appliances in either arch, no moderate or severe asymmetries or facial deformities (for example, cleft lip and palate), intact maxilla and mandibular incisors, stable occlusion, and no severe crowding.

We set the exposure conditions for the LCR (Figure 1A) were 85 kilovolt and 13 milliampere, using a panoramic radiographic unit (Orthopantomograph OC200D, Instrumentarium Dental). We positioned the head using an ear rod and head holder, and images were obtained with the Frankfurt horizontal (FH) plane parallel to the surface of the earth. We obtained the LCR measurements using radiographic software (Dolphin Imaging Software version 11.8, Dolphin Imaging and Management Solutions).

The exposure conditions for the CBCT unit (NewTom VG scanner) were 110 kV, 5 mA, and a 0.25-millimeter voxel size, and the scope of the shot was set to 140 × 140 × 150 cubic mm. We seated the patients at a natural head position with maximum intercuspation before obtaining their CBCT scans. We scanned the CBCT images yielding the the image data in the standard file format known as DICOM (Digital Imaging and Communications in Medicine), which we then analyzed using SimPlant imaging software (Materialise Dental).[20] We identified each anatomic measurement as a 3D point using the software. In addition, the software enabled the simultaneous recognition of the same spatial point in the sagittal, coronal, and axial planes, which were represented in 3 separate windows. The fourth window enabled the recognition of an anatomic point on a volume-rendered window, showing a 3D-reconstructed image of the skull (Figure 1C).

We obtained the 2D CBCT-generated cephalograms by importing the DICOM image data into the software (NNT Viewer, Version 5.3, NewTom) using ray cast rendering algorithm. The working principle of the ray cast algorithm is tracing rays cast from the viewpoint of the observer to the data set,[21] and the values of the voxels from the viewpoint to the plane of projection are summed and then divided by the number of voxels[6] (Figure 1B). The 2D CBCT-generated cephalograms were built by using orthogonal projections (that is, setting the center of projection at an infinite distance from the plane of projection, thus simulating parallel rays). Also, we imported these 2D CBCT-generated cephalograms into the Dolphin software Version 11.8 for analysis.

ABBREVIATION KEY. **2D:** 2-dimensional. **3D:** 3-dimensional. **A:** Point A. **ANS:** Anterior nasal spine. **B:** Point B. **CBCT:** Cone-beam computed tomography. **Co:** Condylion. **CT:** Computer tomography. **FH:** Frankfort horizontal. **FMA:** Frankfort mandibular plane angle. **Gn:** Gnathion. **Go:** Gonion. **IMPA:** Incisor mandibular plane angle. **L1:** Mandibular first incisor. **LCR:** Lateral cephalometric radiography. **Me:** Menton. **MP:** Mandibular plane. **N:** Nasion. **ODI:** Overbite depth indicator. **Or:** Orbitale. **Pog:** Pogonion. **Po:** Porion. **PMP:** Posterior maxillary point. **PNS:** Posterior nasal spine. **S:** Sella. **U1:** Maxillary first incisor.