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Three-dimensional architectural and structural analysis—a transition in concept and design from Delaire's cephalometric analysis

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Abstract. The aim of this study was to present a systematic sequence for three-dimensional (3D) measurement and cephalometry, provide the norm data for computed tomography-based 3D architectural and structural cephalometric analysis, and validate the 3D data through comparison with Delaire's two-dimensional (2D) lateral cephalometric data for the same Korean adults. 2D and 3D cephalometric analyses were performed for 27 healthy subjects and the measurements of both analyses were then individually and comparatively analyzed. Essential diagnostic tools for 3D cephalometry with modified definitions of the points, planes, and measurements were set up based on a review of the conceptual differences between two and three dimensions. Some 2D and 3D analysis results were similar, though significant differences were found with regard to craniofacial angle (C1–F1), incisal axis angles, cranial base length (C2), and cranial height (C3). The discrepancy in C2 and C3 appeared to be directly related to the magnification of 2D cephalometric images. Considering measurement discrepancies between 2D and 3D Delaire's analyses due to differences in concept and design, 3D architectural and structural analysis needs to be conducted based on norms and a sound 3D basis for the sake of its accurate application and widespread adoption.

Keywords: three-dimensional; two-dimensional; cephalometry; norms; computed tomography; architectural and structural analysis.

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Two-dimensional (2D) cephalometric analysis has long been an essential tool in the diagnosis and treatment planning of craniofacial dysmorphosis, as well as for the evaluation of normal craniofacial growth. Among the various cephalometric analyses, architectural and structural craniofacial analysis has attained a unique status due to its evaluation of the mutual balance between the face and cranium on an individual basis.[1,2] It analyzes the craniofacial architecture and surrounding structures through the geometric allocation of four cranial lines (C1–C4) and eight craniofacial lines (F1–F8) on 2D lateral cephalograms.

Recent advances in imaging technology have led to the transition from 2D to three-dimensional (3D) cephalometrics using computed tomography (CT) scan images.[3,4] 3D architectural and structural cephalometric analysis is one of the various CT-based 3D cephalometric analyses proposed, and was first introduced by Bettega et al. in 2000.[5] They constructed five planes (C1, F1, F4, F7, and F8) and two lines (F5, chin) using 12 anatomical reference points. A later version of architectural analysis, put forward by Olszewski et al.,[6] used 22 anatomical reference points and 13 constructed planes (C1–C3, F1–F8, midsagittal, and chin plane) using commercial 3D software. They defined the reference points and planes successfully and reproducibly based on the main reference points and lines of Delaire's cephalometrics.[7] Their analysis, however, still showed some limitations, as well as diverging from the original concept of Delaire's architectural and structural analysis. One limitation was the absence of cranial analysis including cranial height and calvarium-related reference points, such as the summit of the cranium (Sc) and bregma (Br), critical in evaluating the vertical and sagittal growth patterns of the cranium and their relation to the facial architecture. Another limitation lay in the absence of 3D analysis-derived norm data from healthy individuals and their comparison with 2D analysis data, an omission that hinders practical application of their analysis.

3D cephalometric craniofacial analysis is not a simple expansion of 2D analysis using 3D lines and planes. The successful transition from 2D to 3D analysis demands a validation of 3D diagnostic components (points, planes, and measurements), a model orientation in 3D space, and 3D cephalometric norm values, all based on a thorough understanding of the conceptual difference between 2D and 3D. To enable a successful transition from 2D to 3D analysis, we aimed to assess 3D cephalometry by comparing 3D data from normal Korean subjects with 2D data and to suggest a Delaire approach to 3D architectural and structural craniofacial cephalometric analysis using our norm values. We thus review herein 3D-related concepts and present a systematic sequence of 3D cephalometry with norm data from a CT-based 3D architectural and structural analysis of Koreans using modified definitions of the points and planes. A comparison of 3D measurements with traditional 2D cephalometric data for the same individuals is also presented.

Materials and methods

Subjects

Twenty-seven normal Korean adults with skeletal class I (11 males and 16 females; mean age 24.22 ± 2.91 years), sampled at random, volunteered for this study. Clinical and cephalometric examinations with dental plaster models were used to rule out dysmorphosis and malocclusion. The following inclusion criteria were used for subject collection: native Korean, Angle's class I molar key and maxillomandibular skeletal relationship with C1–F1 angle of 83–91°, sella–nasion–A point (SNA) angle of 79–85°, sella–nasion–B point (SNB) angle of 76.5–83°, and A point–nasion–B point (ANB) angle of 0–4° (based on Korean norm studies[8,9]), full dentition except for permanent third molars and no anterior or posterior crossbite, aesthetically acceptable appearance without facial asymmetry (assessed by two authors, Lee and Park), no previous history of prosthodontic, operative, orthodontic, orthognathic or medical treatment, absence of temporomandibular joint disease or oral functional disturbances, and no history of craniofacial trauma. Informed consent was obtained from each subject and this work was approved by the local ethics committee.

Image acquisition

Each subject underwent CT imaging, with the Frankfort horizontal (FH) line perpendicular to the floor, using a high-speed Advantage CT System (GE Medical Systems, Inc., Milwaukee, WI, USA) employing a high-resolution bone algorithm protocol (200 mA, 120 kV, scanning time 1 s, 1 mm scan thickness, a 512 × 512 pixel reconstruction matrix, and 0.48 mm × 0.48 mm × 1.0 mm voxels). All subjects were asked to close their mouth at the maximum intercuspation.

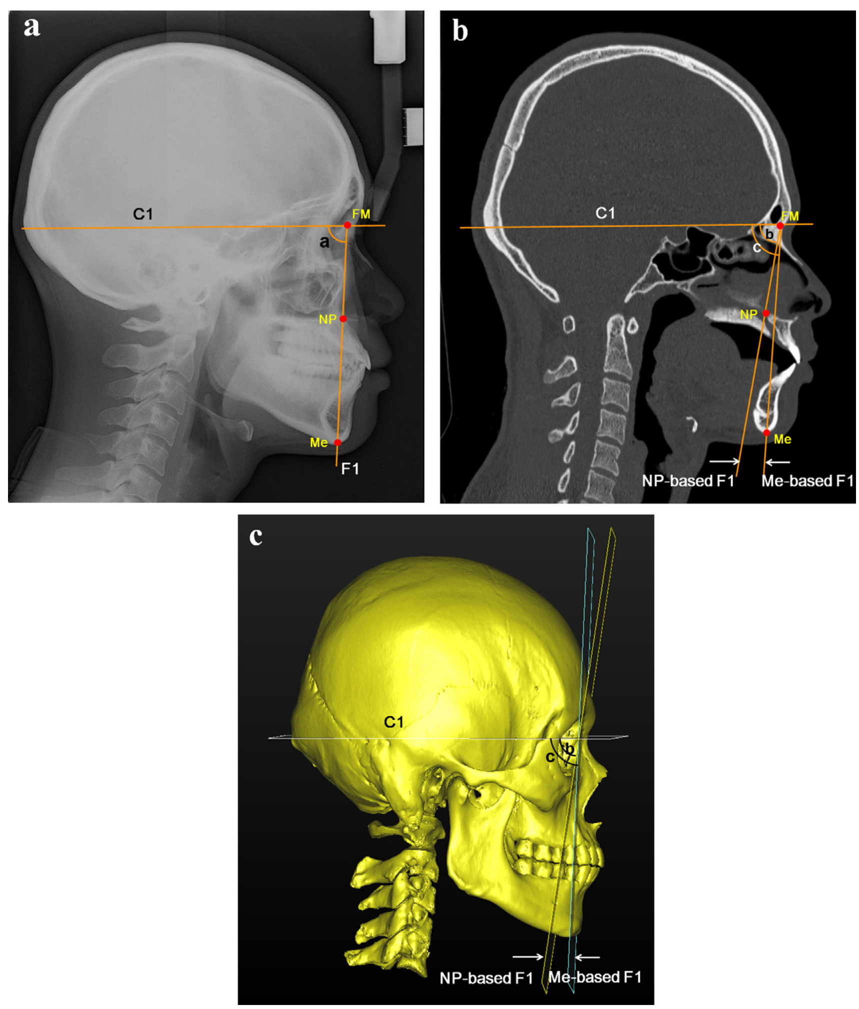

Fig. 1. Construction of F1 in 2D and 3D cephalometric analysis. (a) Line F1 passes through FM, NP, and Me points in 2D lateral cephalometrics. Angle 'a' represents the craniofacial angle between line C1 and F1. (b) Plane F1 passing through FM–NP (NP-based F1) differs drastically from that passing through FM–Me (Me-based F1) in the sagittal sectional view in 3D cephalometrics. Angles 'b' and 'c' indicate, independently, the craniofacial angle between plane C1 and NP-based F1 or Me-based F1, respectively. (c) NP-based and Me-based F1 planes in Fig. 1b are presented on the 3D model.