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Dentomaxillofacial cone-beam CT for orthodontic assessment

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Abstract. Cone-beam computed tomography (CBCT) systems dedicated to craniofacial imaging are now available from several different manufacturers. Potentially, CBCT will permit the use of 3D cephalometrics for orthodontic assessment. A simple method is demonstrated to simulate conventional 2D cephalograms from CBCT image files. Such cephalogram simulations can be used to facilitate transfer of growth projections from existing datasets as a starting point for use of the new 3D paradigm. © 2005 CARS & Elsevier B.V. All rights reserved.

Keywords: Cephalometrics; Cone-beam computed tomography; Digital image processing; Orthodontics

1. Introduction

For more than half a century, the orthodontist has relied upon one or more two-dimensional cephalograms to assess skeletal and dental relationships. With the advent of cone-beam computed tomography (CBCT) specifically designed for imaging the craniofacial structures, three-dimensional assessments are now feasible. While substantial databases exist that have validated traditional cephalometric analyses, this is not yet the case for three-dimensional approaches [1–4]. The purpose of this paper is to demonstrate a method for replicating two-dimensional cephalograms from CBCT volumetric data sets so that direct comparisons can be made between existing two-dimensional databases and the new paradigm of three-dimensional analysis. Both advantages and current shortcomings of CBCT will be addressed. Currently, limitations exist with respect to

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Fig. 1. iCAT CBCT system (ISI, Hatfield, PA, USA).

the demonstration of soft tissue details for three-dimensional cephalometric analyses using CBCT.

2. Methods

The imaging system utilized was an iCAT (Imaging Sciences International, Hatfield, PA) operating at 120($\pm$ 5) kVcp and 3–8($\pm$ 10%) mA with a nominat focal spot of 0.5 mm and a source to detector distance of 67.5 cm (Fig. 1). The image detector was an amorphous silicon/CSi flat panel measuring 20$\times$25 cm with a front panel attenuation of less than 1 mm aluminum equiv. Images were acquired 12 bit in a single 360° rotation using a 20 s exposure cycle. The scan dimensions exceeded 17$\times$13.3 cm. The voxel dimension selected was both 0.4 and 0.25 mm for anatomical skull specimens, and either 0.4 mm or 0.25 mm for patients referred for imaging based upon assessed clinical need.

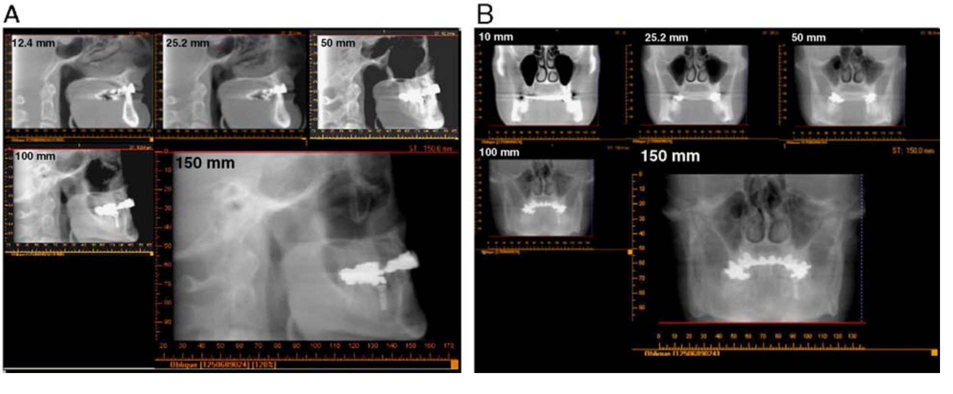

Fig. 2. (A) Simulated lateral cephalograms. (B) Simulated PA cephalograms.

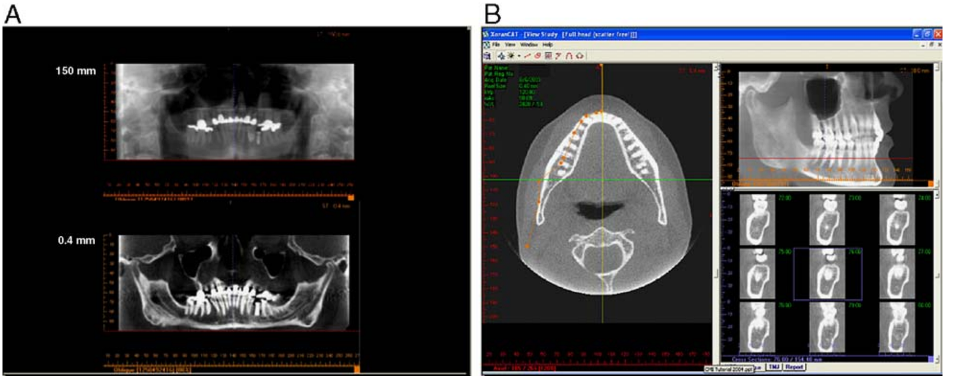

Fig. 3. (A) Simulated panoramic radiographs at 150 mm and 0.4 mm layer widths. (B) Simulated lateral oblique projection with soft tissue profile.

Primary reconstruction was achieved within 2 min for standard resolution and secondary reconstructions were acquired in real time. Images were stored in DICOM format. These secondary reconstructions included a panoramic projection and various 15 cm image layer reconstructed cephalometric projections. For images made using dry skulls, it was possible to make actual linear measurements between selected anatomical points using a vernier caliper for comparison with assessments made using CBCT.

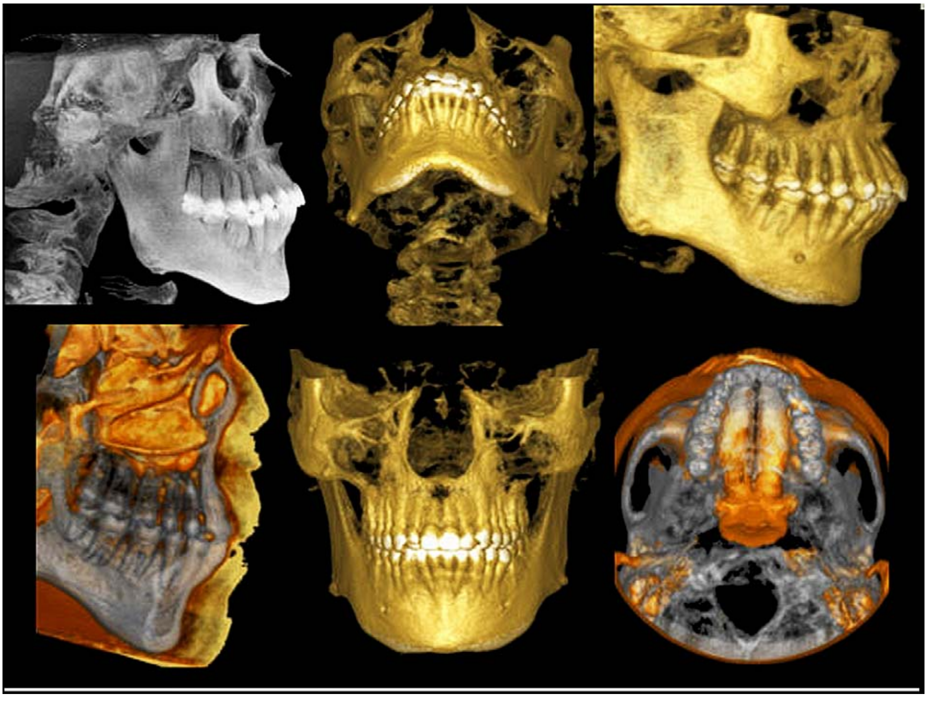

Fig. 4. Anatomical reconstructions made using the iCAT CBCT (ISI, Hatfield, PA, USA).

3. Results

It proved possible to precisely replicate two-dimensional cephalometric projections in all three orthogonal fields and in oblique projection, with a total radiation dose equivalent to four plane film projections using high speed film and screens (Fig. 2A and B). One difference in these reconstructed planes was the absence of magnification and distortion between beam entrance and exit sides of the patient. Moreover, in each case, it was possible to produce slices equal to the dimension of the chosen voxel resolution; hence, anatomic superimposition could be removed to precisely bony define landmarks. Using high resolution mode, the definition of the periodontal ligament space could sometimes be discriminated. Tooth dimensions and angulations were defined on CBCT without distortion, unlike with traditional methods. It was also possible to produce a number of special projections, including panoramic views (Fig. 3A), and lateral-oblique projections of the jaws combined with the soft-tissue profile (Fig. 3B). While soft-tissue definition in patients is sufficient to determine the patients profile, greater clarity of soft tissue definition could improve assessment of bulk and insertion patterns of the maxillofacial musculature that impacts on the stability of tooth position following orthodontic treatment.

Cone-beam CT affords the possibility of providing 2D simulated cephalographic projections from 3D datasets. The ability to reconstruct such traditional cephalograms means that existing data bases can still be used for orthodontic treatment projections. Undoubtedly, orthodontic treatment planning will be refined using the more powerful 3D image projections that can now be generated (Fig. 4).

4. Conclusions

CBCT using the iCAT system permits reconstructions that are comparable to traditional cephalometric projections. This means that existing databases regarding treatment projections can be used as a baseline to three-dimensional cephalometric assessments.

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