Volumetric cone beam computed tomography in neuromuscular dentistry

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Three-dimensional imaging for dentistry is here and has already proven to be the practical alternative to traditional 2-D dental radiology, as expected. A single volumetric cone beam computed tomography (CBCT) scan can now replace the conventional cephalogram, panoramic, PA skull and tomograms of the TMJs, implant sites and paranasal sinuses in one 10–20 second scan. This new technology is already redefining cephalometric analysis.

History

CT was invented in 1972 by British engineer Sir Godfrey N. Hounsfield of EMI Laboratories, England, with the first "CAT-Scans" patent granted to Robert S. Ledley on November 25, 1975. Most conventional medical MDCT’s incorporate a fan shaped beam (Fig. 1) whereas dental CBCT systems today utilize a cone shape beam (Fig. 2). With
conventional CT, X-ray is produced as the gantry rotates the X-ray tube and detector around the patient (Fig. 2) producing an image or “slice” with each 360 degree rotation and then stacks the multiple scans and slices.

In a cone beam computed tomography geometry, the entire subject is exposed just once from a single point source using an amorphous silicon (aSi:H) flat-panel sensor, CsI, CMOS or CCD as its detector. A single rotation CBCT scan results in a volumetric scan of the entire subject with complete data acquisition in just two to three minutes.

In March 2001, the NewTom QR-DVT 9000 became the first CBCT system to receive FDA approval in the United States (Fig. 3). Followed in 2003 by the Imaging Sciences International i-CAT incorporating...
similar CBCT technology but in a sit-down and relatively affordable system (Fig. 4).

In 2008, NewTom introduced the upright VG system (Fig. 5) utilizing its exclusive Smart Beam Technology with significant reduction in radiation dosage.\(^1\)

With a single 10–20 second CBCT scan and a large FOV (field of view), we now have the full 3-D volume of the head and neck from Nasion down to C4 including a panoramic, TMJ’s, pharyngeal airway, paranasal and maxillary sinuses, etc., with a single scan. Three-dimensional rendering and the MIP (maximum intensity projection) in Figure 6 will undoubtedly demand new cephalometric landmarks and analyses (Fig. 7) in addition to enhancing patient understanding and acceptance.

Three-dimensional data will continue to enhance our existing knowledge with:

1) A measureable assessment of bone quality and density (Hounsfield units).
2) The ability to measure arch widths before and after treatment (Fig. 8).
3) Actual impacted dentition orientation in three dimensions (Fig. 9).
4) Upper airway evaluation (Fig. 10).
5) Pharyngeal volumetric airway evaluation before and after treatment (Fig. 11).
6) TMJ morphology and condylar position (Fig. 12).

Yet, with this technology comes the personal responsibility to further one’s education on 3-D anatomy—an absolute necessity for a proper, comprehensive neuromuscular diagnosis. We must also learn how to accurately create the necessary images from this single scan.

For example with 3-D pans, we must increase the reconstructed cut-plane width to incorporate the coronoid processes to assess potential hyperplasia and impingement and to incorporate maxillarybone as well as basal bone for potential ossifications of the stylohyoid ligament (Eagles syndrome). Failure to do so will result in a myriad of false negatives and potential misdiagnoses.

Proper mapping of the anatomy is no more critical than for the temporal mandibular joints, best illustrated in the below axial views. The three axial images (Submental view) in Figures 13–15 are actually on the same patient, but demonstrate three different and distinct condylar morphologies. Which one would you map for your TMJ study? The answer is Figure 13.

Figure 13 demonstrates bilateral kidney shaped condyles, while both Figures 14 and 15 are indicative of potential osteogenic degeneration.

Too often, Figure 14 is mapped with the straight TMJ tool (Fig. 16), creating the false positive of bi-
lateral avascular necrosis, as seen here in the bilateral coronal views (Fig. 16), an artefact with invasive consequences!

The operator should have continued to Figure 13, and using the oblique or panoramic tool, drawn the necessary Bezier curve incorporating both lateral and medial poles (Fig. 17).

_Soft-tissue legalities_

There has been a great deal of discussion and unwarranted fear being disseminated by a few self-serving oral and maxillofacial radiologists in addition to the manufacturers of smaller FOV systems. Implying that we are now responsible for diagnosing brain tissue!

Three-dimensions do not change the fact that brain tissue maladies and diagnoses are not taught in dental school and that CBCT systems by their very nature are not to be used in lieu of a medical CT or MRI for soft-tissue diagnoses.

With the cephalograms I read, an image encompassing more cranial anatomy than the typical large FOV CBCT scan, I see one or two fibrosarcoma in sella and the thyroid every month because I look for them. But I see few articles in our dental journals that address these very issues, and I suspect that our medical radiology journals also devote little ink to periodontal disease.

A review of the current literature suggests:

“In comparing cone-beam technology with conventional CT, it should be kept in mind that cone beam systems dedicated to maxillofacial diagnostics by their physical nature do not provide enough low-contrast resolution to discriminate soft tissue structures.”

“Where it is likely that evaluation of soft tissues will be required as part of the patient’s radiological assessment, the appropriate imaging should be conventional medical CT or MR, rather than CBCT.”

Statement 8 comes close to this in recommending that CBCT not be used where soft tissue assessment is a significant aspect of the need for imaging.

_Conclusions_

CBCT has been responsible for a significant reduction in radiation as compared to medical CT (68 µSv vs. 1200–3300 µSv). One CBCT scan is equivalent to approximately five plain film panoramic radiographs, significantly less than a full-mouth series. CBCT images can be saved and viewed as native DICOM, PDF and JPEG compressed files and imported into most third-party patient management software programs.

As a result of this evolution, there are now numerous free DICOM 3-D multiview readers available for both PC and Mac platforms, yet this author prefers the Anatomage Invivo 3-D software for its ease of use and options. CBCT has also been responsible for making CT technology affordable while opening up paths for future research and innovation, particularly in neuromuscular orthopaedics.

_Editorial note: a complete list of references is available from the publisher._

_Dr Greenan is an internationally known X-ray authority and president of Imaging Systems Inc., the Academy for Advanced Radiographic Studies, author of A Practical Atlas of TMJ and Cephalometric Radiology and has published in numerous journals and textbooks on dental implants, orthodontics and TMJ radiology._

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