Three-dimensional craniofacial imaging

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The clinical application of 3-dimensional craniofacial imaging is one of the most exciting and revolutionary topics in dentistry. Cone-beam computed tomography (CBCT), also known as cone-beam volumetric tomography (CBVT), has followed the trend of computed tomography (CT) in medicine, in which, after the introduction of the first practical CT in 1971 by Dr Hounsfield in England, clinical applications were immediately recognized. CT has since become one of the most important radiological examinations worldwide. In the decade after CT was first introduced, 18 manufacturers offered medical CTs.

Data from the International Commission on Radiological Protection (ICRP) show that the annual number of CT examinations in the United States rose from about 5 million in 1983 to over 20 million in 1995 (ICRP Publication 87). In addition, the frequency of CT examinations is increasing rapidly, from 2% of all radiological examinations in some countries a decade ago to 10% or 15% at this time. However, despite significant advancements in medical CT technology to improve speed and resolution, patient doses in CT have not decreased in contrast to radiography, in which a nearly 30% reduction has been documented in last decade (ICRP Publication 87).

In dentistry, CBCT was introduced in the United States at Loma Linda University in 2000 and has since seen rapid growth (as of this writing, an estimated 40-50 CBCT devices are in operation), widespread clinical application, and significant technological development, including improved speed of imaging and resolution.

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CBCT vs medical CT

It is important to distinguish CBCT from traditional medical CT devices; they are not the same. The 2 principal differences are the type of imaging source-detector complex and the method of data acquisition. The Figure illustrates the basic difference between these 2 technologies. The x-ray source for CT is a high output rotating anode generator; for CBCT, it can be a low-energy fixed anode tube similar to that used in dental panoramic machines. CT uses a fan-shaped x-ray beam from its source for imaging and records the data on solid-state image detectors arranged in a 360° array around the patient. CBCT technology uses a cone-shaped x-ray beam with a special image intensifier and a solid-state sensor or an amorphous silicon plate for capturing the image. Medical CT devices image patients in a series of axial plane slices that are captured either as stacked slices or from a continuous spiral motion over the axial plane. Conversely, CBCT uses 1 rotation sweep of the patient, similar to that for panoramic radiography. Image data can be collected for either a complete dental or maxillofacial volume or a limited regional area of interest.

Accuracy of CBCT

To address the accuracy of measurements taken from the CBCT images, one must understand the fundamental differences between traditional dental imaging and orthogonal projections. In traditional dental imaging with plain films, there is always some projection error because the anatomic region of interest is some distance away from the film and is projected onto it. Panoramic radiographs have an unusual projection because the main path of the x-ray beam comes from a slight negative angulation. In acquiring the skills to interpret these images, the diagnostician accounts for these imaging artifacts while learning to read the films. In CBCT, the projection is orthogonal, indicating that the x-ray beams are approximately parallel to one another, and, because the object is very near the sensor, there is very little projection effect. In addition, this effect is handled by the computer soft-

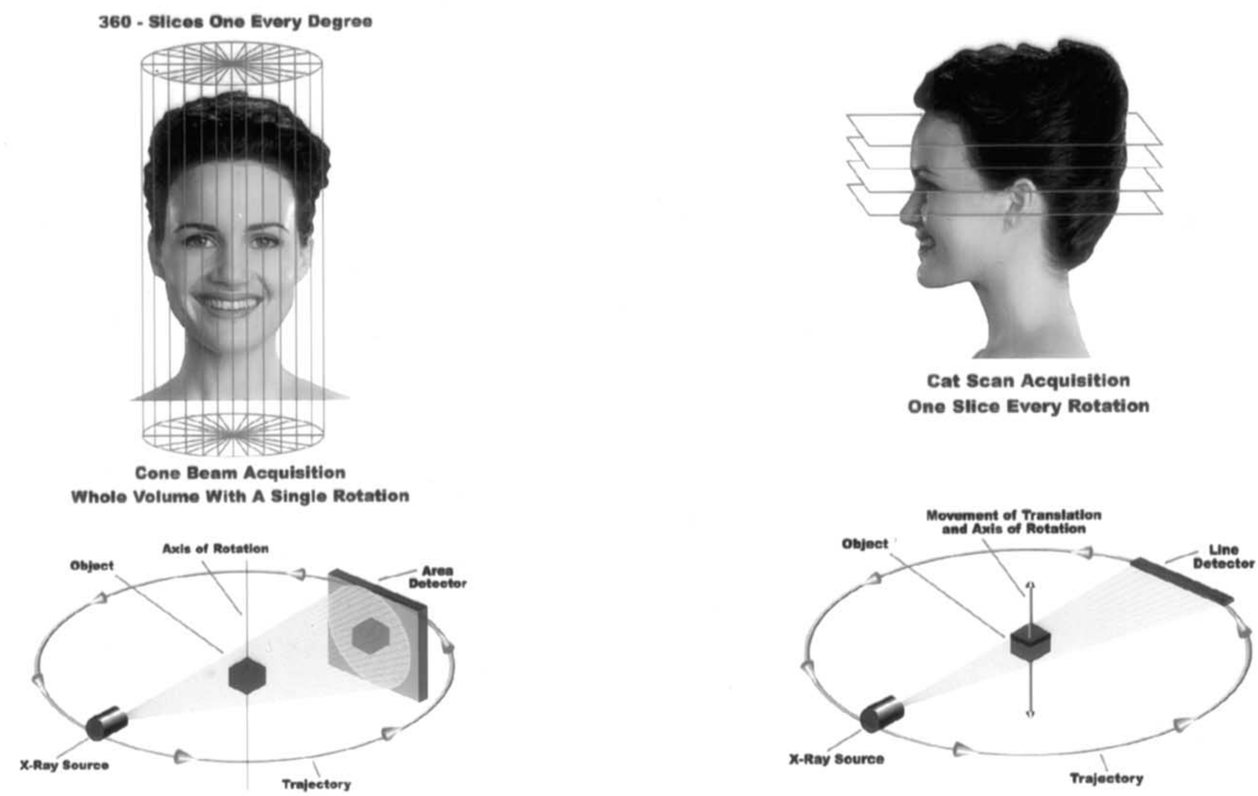

Fig. Differences in image acquisition between **A**, CBVT and **B**, traditional CT. Image courtesy of Drs Ivan Dus and Carl Gugino, Aperio Services, Inc, Sarasota, Fla.

ware, resulting in 1-to-1 measurements. To ensure that this error correction is functioning as well as other operational systems, a water phantom is used to calibrate the device daily.

Effective absorbed radiation dose

A recurrent issue is the effective absorbed radiation dose of an imaging session with CBCT. Radiation dosimetry in dentistry is a rather complicated and often misunderstood subject. Part of the confusion is due to the various terms used, the units of measurement, and differences in study methodology. As far as terminology, the measured doses are collected to produce the *mean tissue absorbed dose* with units in micrograys (μGy). The percentage of the body exposed is accounted for and the mean tissue absorbed dose is converted to the *equivalent dose* with the units in microsieverts (μSv). However, different tissues have more or less sensitivity to radiation-induced damage, and these sensitivities are taken into account as the equivalent dose is converted to the *effective dose*, with units in microsieverts.

The maxillomandibular volume acquired with CBCT devices can include image information for both arches and other views, such as panoramic or occlusal. The volume can be reformatted in a process termed *secondary reconstruction* and viewed from numerous perspectives by using the accompanying software. The costs, efficiency, and benefits of this are very favorable, because 1 imaging session provides multiple views. This must be taken into account when prescribing radiographic images. For example, in treatment planning for a patient requiring dental implants in both arches, panoramic and CT examinations of the maxilla and mandible could be prescribed. The effective dose contribution from the panoramic examination (2.9-9.6 μSv[12]) and individual CT examinations of the maxilla (17.6-656.9 μSv) and the mandible (124.9-250.3 μSv) could total 145.4-916.8 μSv. This type of analysis can be factored into determinations of risk and benefit of radiographic imaging. However, these figures are not absolute and could change with machine design, settings, and imaging parameters.

Next generation CBCT

There have been recent advances in CBCT technology, and there will be more to come in the months ahead. In general, these advancements have increased the speed of image acquisition and improved resolution.