Cone Beam Computed Tomography Scanning and Diagnosis for Dental Implants

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KEYWORDS

• CBCT • Oral and maxillofacial surgery • Dental implants

KEY POINTS

- CBCT has become an important new technology for oral and maxillofacial surgery practitioners.
- CBCT provides improved office-based diagnostic capability and applications for surgical procedures, such as CT guidance through the use of computer-generated drill guides.
- A thorough knowledge of the basic science of CBCT as well as the ability to interpret the images correctly and thoroughly is essential to current practice.

Recent advances in cone beam computed tomography (CBCT) have made office-based CBCT scanners affordable for oral and maxillofacial surgeons who now use this cross-sectional imaging technology on a daily basis for a wide variety of clinical problems.[1–4] CBCT is a form of helical CT scanning that has the advantage of providing higher-level bone imaging in a dental setting at a significantly lowered dosage of radiation.[5] Radiation dosage in dental offices has been a topic of recent controversy in the public media, and indications for CBCT use should follow the as low as reasonably achievable (ALARA) principle.[6] This is especially important with regard to use in children.[7] Aside from the use of CBCT for the examination of impacted teeth,[8,9] supernumerary teeth,[10] detection of dental fractures,[11] maxillary sinus anatomy,[12] mandibular canals,[13] endodontic lesions, extra root canals, caries and periodontal lesions,[14] temporomandibular joint (TMJ),[15,16] skeletal jaw deformities,[17] orthodontics,[18,19] acquired deformities and reconstruction,[20] oral and maxillofacial trauma,[21] pathology,[22,23] and airway,[24] it is also used for dental implants.[4,25–29] Office-based CBCT has the further advantage of being used for dental implant treatment planning and CT-guided dental implant placement. CT-guided dental implant surgery through the use of surgical drill guides[30–36] allows precise dental implant placement trajectories, depth control, minimally invasive flapless procedures, and immediate temporary prosthesis placement.[30–36] Tomography is imaging by sections and is performed by the rotation of an x-ray source around the single axis of an anatomic structure. A sensor absorbs the x-ray opposite to the source during the movement of the device.[37] Developed in the 1930s by Alessandro Vallebona,[38] plain tomography was an improvement over plain radiography. Plain tomography allowed the removal of superimposed structures to be viewed as a 2-D slice. In dentistry, a form of conventional plain tomography

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that continues to be widely used is the orthopantogram or panoramic radiograph.[39] Panoramic radiography uses a variable depth of field or focal trough,[40] allowing anatomy at the target level to remain sharp while other structures are blurred in the background. The term, orthopantomogram, is used to describe the panoramic radiograph, because the teeth are displayed in the orthogonal plane. Modern tomography involves the taking of multiple projections of an anatomic region and feeding the data into a specialized reconstruction software algorithm for computer processing.[41,42]

CT scanning was first discovered by Godfrey Hounsfield in England in the early 1970s,[43–45] for which he and Allan MacLeod Cormack received a Nobel prize in 1979.[46,47] With the ability to use powerful computer algorithms that process data from a large number of sectional images, or slices, a 3-D image can be reconstructed. The CT scan became an improvement over the 2-D sectional imaging of plain tomography.[48] CT is based on projective geometry analysis of the slice data generated by rotation around a patient as a result of the synchronous movement of the x-ray source and the sensor.[49] The earliest cesium iodide scintillator sensors were positioned opposite to the x-ray source.

It was in the late 1960s that Hounsfield first conceptualized that it was possible to determine the inside contents of a box by taking radiographs from multiple angles around an object. Based on the basic principles of projective geometry, the first CT scanner was built with a moveable x-ray tube and sensor connected by a rod with the pivot point as the focus. The image created by the beam in the focal plane appeared sharper, with the images of the superimposed structures becoming background noise. Hounsfield designed a computer that could accept the 2-D x-ray data from different angles to create a series of images of the object formatted as slices. In 1971, the first commercial CT scanner was developed for scanning the brain, which was later followed by the full-body scanner. Hounsfield, in the process of creating the first CT scanner, was unaware at the time that Cormack had developed similar mathematical theorems. Robert Ledley, at Georgetown University, later developed an improved full-body CT scanner that did not require a water tank.[50] Developed by Hounsfield at a research branch of EMI, a company best known for its music and recording business, CT was originally known as the EMI scan or the Beatles scan.[51–53] CAT, originally termed computed axial tomography, was shortened to CT scan. The CT sensors originally were made from cesium iodide and later replaced with ion chambers containing xenon gas under high pressure. CT scanners create images as slices of patients in different planes through the use of tomographic reconstruction fast Fourier mathematical calculation algorithms based on a matrix memory whereby points of data are processed.[54] The algorithm of these calculations is based on the Radon transformation, named after Johann Radon's work in 1917.[55,56] The Radon transformation is the integral of a function over straight lines, and it represents the scattering of data obtained as the output of a cross-sectional tomographic scan (**Fig. 1**). The use of the inverse of the Radon transformation allows the reconstruction of the scattering data and is the mathematical foundation for CT.[57,58] This process is known as the back projection[59–62] and reverses the acquisition geometry, storing the results in another memory array. The Radon transformation is also known as a sinogram, which resembles the images of CT scans.[63] The Radon transform of a direct delta function is a distribution supported within the graph of a sine wave. Consequently, the Radon transform of numerous small objects can be seen graphically as blurred sine waves with different amplitudes and phases. The inverse of the Radon transform is thus used to reconstruct the original density from the scattering data (**Fig. 2**) and thereby forms the mathematical basis for CT reconstruction.[64]

The analysis of CT data can be performed by using 2 types of algorithm method: filtered back projection (FBP)[65] and iterative reconstruction (IR),[66] which both gives inexact results and represents a compromise between computation time and accuracy. FBP requires less computation time compared with IR, but IR has decreased artifacts.[67]

In digital imaging, a single point in a raster image is known as a pixel (*pix* [pictures] and *el* [element]). The pixel is the smallest 2-D addressable element of a picture on a screen that can be controlled. Raster images are the basic images that appear on a computer monitor and, depending on the software, can be in high or low definition. A volumetric pixel in 3-D space is known as a voxel (*vox* [volume] and *el* [element]), and when aggregated forms a 3-D volume-rendered image.

$$Rf(L) = \int_L f(x)\,|dx|.$$

Fig. 1. Radon's transform formula.