CAT imaging in periodontics and implant dentistry

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ABSTRACT

Computed Axial Tomography (CAT) also known as, computed tomography, is a sophisticated x-ray procedure. Recent concepts in the CAT scan enabled dentists to access the structural changes of alveolar bone effectively. New approaches for CAT scanning allow dental specialists to conduct densitometric assessments of dentoalveolar structures more accurately. Periodontal applications of CAT include the detailed radiologic anatomy of alveolar processes, density of bone surrounding the tooth and approximation to air spaces. Image analysis software permits bone mass mineralization to be quantified by means of CAT data. CAT has also been used to study assessing periodontal breakdown and its marked superiority in the diagnosis of furcation areas and dental implant treatment planning. This review gives a comprehensive discussion of CAT scan imaging and its applications in Periodontics and Implant dentistry.

Key words: Alveolar bone height; CAT scan; Dental implant; Periodontal pocket depth

Introduction

Computed Axial Tomography (CAT) also known as, computed tomography (CT), is a sophisticated x-ray procedure. CAT uses x-rays to portray a cross-sectional image of an object without superimpositions. The CAT scanner makes multiple projections of an object with a thin, fan-shaped beam of x-rays. Radiation detectors measure the object’s x-ray attenuation at each of these projections, and a computer reconstructs the attenuation data to produce a cross-sectional image, or “slice”, of the object.1 Mathematician J Radon laid the theoretical foundation for its development in 1917 when he demonstrated that the image of an object could be produced from an infinite set of all of its projections.2 The first clinical CT x-ray unit was developed in 1972 by GN Hounsfield in England.3 This paper evaluates the usefulness of CAT imaging in periodontics and implant dentistry.

CAT revolutionized clinical imaging by three major improvements over traditional radiography. a) CAT eliminated superimpositions by mathematical recombination of multiple projections of the structure and provides a cross-sectional image, the elements of which are free of images of superimposed structures. b) CAT permits the resolution of objects that differ only slightly in their attenuation of radiation. For example, the gray matter and white matter of the brain differ by 1% in physical density and by less than 1% in electron density and yet CAT can distinguish the two tissues. c) CAT data are acquired digitally and therefore offer greater flexibility in the processing, storage, transmission, analysis, and reformatting of images than does film-based imaging.4,5

Technology behind CAT Scan

X-ray source: An ionizing radiation is passed through an object and image results from variations in attenuation of the radiation by different regions of the object. This beam is typically fan-shaped and collimated to a width controlled by the operator, usually from 1 to 10 mm.

X-ray beam attenuation: Transmission of the x-ray beam through an object is determined by the linear attenuation coefficients of all the structures in the object through which the beam passes.

CAT x-ray detectors: These detectors are either, scintillation crystal, photomultiplier tubes or gas ionization chambers. They absorb x-ray photons and convert them into electrical currents proportional to photon energy. This analog information is then digitized and sent to the CAT computer for reconstruction.

Motion of the object, source and detectors in CAT: Most modern CAT units use one of the following three methods of moving an object, the x-ray source, and the detector: So-called “rotate-rotate” scanners rotate both the x-ray source and the detector array (180 degrees from the x-ray source) around the object once per slice. “Fixed-rotate” scanners have a non-moving, 360-degree array of detectors, and rotate the x-ray source once around the object for every slice acquired. “Helical/spiral” scanners rotate x-ray source continuously in one direction without stopping and reversing between slices.1 In helical/spiral scanning, the object is moved continuously throughout the scan so that the x-ray beam traces a spiral path across the object. The continuous motion of the x-ray source and object results in decreased scan time, a lower likelihood of object (patient) movement and motion artifact. Overlapping slices decrease the likelihood that a small structure will be overlooked due to partial volume averaging. Non-helical/spiral CT will be hereafter identified as “conventional CT.”1

Data reconstruction: After data are collected by the CT computer, the image is reconstructed by one of several reconstruction algorithms to calculate the linear attenuation coefficient of each voxel in a slice and then to assign a CT number to each voxel. CT number (Hounsfield number) of-1000 represents air, ‘0’ represents water, and +1000 represents bone. As with any other digital image, image analysis software may be used to measure distances, angles, pixel intensity, and volume of structures within the scanned object. Two-dimensional reformats are of particular value in the imaging of a structure that runs more or less parallel to the original scan plane. Two-dimensional reformats may be constructed along many different planes from the same study and has been proven useful in two-dimensional cuts perpendicular and radial to the alveolar ridges for dental implant treatment planning. Three-dimensional reformats permit the portrayal and measurement of
surfaces and volumes of bone, soft tissue, and air spaces in an object.\textsuperscript{1}

**Resolution of CT**: Spatial resolution is the ability of the scanner to portray as separate images two objects placed close together. Modern CT units have a spatial resolution of less than 0.5mm, which is determined by CT scanner design, CT computer reconstruction methods, and the video display. A high-resolution CT study is performed at a slice thickness of 1 or 2 mm, compared with "routine" studies of 5, 8, or 10 mm slice thickness. "High-resolution CT" can also mean a non-clinical unit,\textsuperscript{6} with a substantially higher spatial resolution (60 microns) allows for the true three-dimensional reconstruction of a segment of trabecular bone. Contrast resolution is the ability of the scanner to distinguish between two objects differing only slightly in x-ray attenuation or density. Current CT units have a contrast resolution of 0.5% compared to Plain-film radiography, i.e., 10%. CT contrast resolution can be further improved in animal and human subjects by the injection of contrast agents with an atomic number substantially different from that of soft tissue.

**Applications**

CAT is primarily designed to evaluate the structure. The following applications have been selected to illustrate the major applications of CAT to the oral region.

**Anatomy**: CAT can be useful for the study of atomic structure. A detailed radiologic anatomy of the alveolar processes using specialized two-dimensional (dental implant) reconstruction software was described by Yanagisawa.\textsuperscript{7}

**Bone mass and bone mineralization**: CT may be used for the non-invasive estimation of bone mass in a method called quantitative CT or QCT.\textsuperscript{8,9} Of the several methods available for bone mass determination, QCT is relatively sensitive (3 to 4 times that of single photon absorptiometry and twice that of dual photon absorptiometry), has intermediate precision (2-5%, better than that of single-photon absorptiometry but not as good as that of dual-photon methods), and variable accuracy of 5-20% (spanning the range of other available methods). QCT has been applied to the analysis of the trabecular bone mineral density in the mandibular alveolar process in edentulous and dentate post-menopausal women,\textsuperscript{10,11} of cortical bone density in the alveolar process of edentulous regions of postmenopausal women, and to the assessment of the adequacy of mineralization following autologous alveolar ridge augmentation.\textsuperscript{12}

**Dental implant treatment planning**: Two-dimensional reformats of CT scans of the maxillary or mandibular alveolar process have been used for treatment planning of dental implants. "Panoramic" 2-D reconstructions of the length of the alveolar ridge and cross-sectional reconstructions of the buccolingual and superoinferior dimensions of the ridge may be obtained through proprietary software packages,\textsuperscript{13} by eliminating superimpositions and distortion. Patients were advised to wear wax rims containing radiopaque markers during the CT scan, to help the clinician more precisely identify sites for implant placement.\textsuperscript{14}

Indications of CAT for dental implantology includes, posterior maxillary or mandibular sites where conventional radiography shows inadequate bone, anterior maxillary sites when multiple implants are planned, cases in which complete maxillary or mandibular subperiosteal implants are planned, and cases in which an evaluation of buccolingual ridge dimensions is required.\textsuperscript{15}

**Periodontal diagnosis**: CT imaging techniques could be beneficial in assessing periodontal breakdown and its marked superiority in the diagnosis of furcation areas with greater resolution, repeatability, and accuracy compared to the clinical examinations performed.\textsuperscript{16,17} 3DX multi-image micro-CT examinations performed to confirm or exclude dental infection or peri-implantitis.\textsuperscript{18}

**Conclusion**

CT is most often used for the evaluation of the structure rather than function. The principal advantages of this method are the freedom from superimposition of structures in the plane parallel to the x-ray beam, the ability of the system to distinguish between objects of similar density (contrast resolution), and the capture of data in digital form for subsequent analysis and reformattting. The principal disadvantages of CT are the high radiation dose relative to that of plain-film radiography, the high cost, and the relatively long time of image acquisition, requiring the subject to be motionless for several seconds, particularly if subsequent two- or three-dimensional reformatting is desired. CT scans have been evaluated in the originally acquired scan plane and in two and three dimensionally reformatted images for the study of anatomy, growth and development, bone mineralization, salivary gland disease, trauma diagnosis and response to therapy, three-dimensional solid modeling, and dental implant treatment planning. Relative few clinical studies have included prospective comparison between CT and other imaging methods, or between various types of CT imaging.

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**References**

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