

Role of Imaging Modalities in Dental Implantology

Dhafer Saeed Alasmari¹, Mohamed Abdulcader Riyaz²

ABSTRACT

Dental implants have transformed the treatment options for replacement of missing teeth. Success of the dental implants depend on meticulous treatment planning which depends on precision and accuracy of diagnostic information of the patient's anatomy at the proposed implant site. Even though many modalities are available for the implant site imaging, the technique should be adopted according to the case and the clinician's ability to interpret the image acquired. The present article focuses on various diagnostic imaging modalities available for implantology.

Keywords: Dentistry; Implants; Radiology

INTRODUCTION

Imaging has an important role in dental implant procedures. It imparts an accurate and reliable details of the patient's anatomy. Standard projections comprises of intra-oral (periapical, occlusal) and extra-oral (panoramic, lateral cephalometric) radiographs. The other more complex imaging techniques include conventional X-rays, computed tomography (CT), and cone beam computed tomography (CBCT).¹ Imaging of the proposed implant site is required to identify underlying bony pathologies, undercuts and concavities, to find out whether the patient can tolerate the surgical procedure, to assess bone density to know the approximation of vital anatomical structures and to estimate the number, dimensions, orientation, location, and prognosis of the implant to be inserted. The need for additional bone treatments should be considered.²

Types of imaging modalities

The most important imaging modalities in the past were periapical radiographs and conventional dental panoramic tomography. But, as these techniques provides 2-dimensional view thus have their geometric limitations and does not offer a complete outlook on the patient's anatomy.³ Penarrocha M et al⁴ conducted a radiologic study of marginal bone loss using panoramic radiographs, conventional periapical and digital radiographs around 108 dental implants after 1 year of prosthetic loading and observed that panoramic radiographs were less accurate than conventional periapical films and digital radiographs in the assessment of peri-implant bone loss. Panoramic radiographs also offer less resolution and sharpness than periapical radiographs. However, in spite of these limitations, it is yet used as it is relatively inexpensive and available readily. To overcome these shortcomings, newer techniques that provides a 3-dimensional information of the patient's anatomy such as computed tomography (CT) and cone beam CT have been introduced. These computer-assisted techniques provide dentist a realistic view of the jaw anatomy which can help to accurately plan treatment suitable according to the patient's needs.³

Zonography

Zonography is a variation of the panoramic X-ray machine that

provides cross-sectional images of the jaws. The tomographic layer obtained is relatively thick. This technique enables operator to assess the relationship of critical structures to the implant site in different planes. However, this technique cannot determine different bone densities and diseases at the site of implant placement. The other shortcoming of this technique is that it provides a blurred appearance due to superimposition of the adjoining structures over the obtained image and thus limiting its role as a diagnostic tool.⁵

Conventional Tomography

Conventional Tomography is a method that obtains clearer image of the structures lying within a plane of interest. The film and X-ray beam progress with respect to each other and consequently blurring out structures.⁶ The magnification factor of this imaging technique is stable in all directions. Conventional tomography is appropriate for planning single implant sites or for those within a single quadrant.⁷

Computed tomography

Computed tomography provides required three-dimensional (3D) details on craniofacial and dental anatomy for the diagnosis and treatment planning for craniofacial reconstruction as well as for the placement of dental implants.⁸ The most relevant indications for dental CT in the preoperative evaluation of dental implant placement includes evaluation of height and thickness alveolar bone in cases of atrophy, consideration of the positions and condition of the structures important for proper implant placement (e.g., location of the neurovascular bundle and the incisive and mental foramina, inferior alveolar canal, floor of the maxillary sinus, pneumatization of the maxillary sinus, nasal fossa), diagnosis and treatment planning in maxillofacial surgery, assessment after implant and bone graft placements and estimation of bone resorption and root retention, and evaluation of various lesions of the facial skeleton.⁹

Computed tomography can be categorised into 2 types according to acquisition of x-ray beam geometry, i.e. fan beam and cone beam. An x-ray source as well as solid-state detector are mounted on a rotating gantry in case of fan-beam scanners. Data are acquired using a narrow fan-shaped x-ray beam transmitted through the patient. The patient is diagnosed usually in the axial plane slice-by slice and the obtained images are interpreted by stacking the obtained slices to achieve multiple 2D representations. In case of conventional helical fan-

¹Assistant Professor, Department of Periodontology, Vice Dean for Clinical Affairs, ²Assistant Professor, Maxillofacial Diagnostic Sciences, College of Dentistry, Qassim University

Corresponding author: Dr. Mohamed Abdulcader Riyaz.S.S., Assistant Professor, Maxillofacial Diagnostic Sciences, College of Dentistry, Qassim University, Buraidah, Qassim province, KSA

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beam CT scanners, the linear array of detector elements used is actually a multi-detector array which allows multidetector CT (MDCT) scanners to obtain upto 64 slices at the same time, thus decreasing the scanning time as compared to single-slice systems. This configuration also allows generation of 3D images at significantly lower radiation doses than single detector fan-beam CT arrays.¹⁰ The latest modalities of CT are dual source CT, 256 slice CT, multislice CT, inverse geometry CT, etc. CT imaging procedures that combine axial with multiplanar reconstructed images in multidetector CT (MDCT) offers highest accuracy, with 100% specificity and 93% sensitivity.⁸

Computed Tomosynthetic Radiography: Tuned Aperture CT (TACT)

Another method based on optical aperture theory, referred to as TACT for dentoalveolar imaging acts as a substitute to film based tomography and CT.¹¹ It uses 2-D periapical radiographs obtained from various projection angulations as base images and allows retrospective generation of longitudinal tomographic slices (TACT-S) of the area of interest, lining up in the Z axis. Thus, it provides a 3-D information from any number of arbitrarily oriented 2-D projections.¹² Available data suggests that TACT imaging can efficiently detect subtle or recurrent decay and can locate any crestal defect around implant fixtures and natural teeth. TACT offers a number of benefits as the projection geometry can be analysed after individual exposures, radiation doses are comparatively low and problems of patient movement are also less significant.¹¹ Liang H et al¹³ investigated tuned aperture computed tomography (TACT) as an alternative to conventional tomography for cross-sectional imaging of potential implant sites and reported that TACT provides an alternative to conventional tomography for pre-surgical implant imaging.

Denta Scan

Dentascan is a commercially available desktop interactive software program that provides a comprehensive assessment of the bone pre-operatively for implant surgery. It is a computed tomography (CT) software program that permits imaging of the mandible and maxilla in three planes i.e. cross-sectional, axial and panoramic. It offers advantages of assessing radiographs in two or three dimensions, assess bone volumes and density, make direct measurements, manipulate the images to simulate implant placement or bone grafting procedures, as well as can view the images in all the three planes at the same time.¹⁴

Cone Beam Computed Tomography

Cone beam computed tomography (CBCT) is a comparatively newer technique which was introduced as an alternative to multidetector CT and is considered appropriate for a wide range of craniofacial indications.¹⁵

The use of CBCT technology in clinical practice provides a number of potential advantages for maxillofacial imaging compared with conventional CT. As most CBCT units can be adjusted to scan small regions for specific diagnostic tasks, hence, the size of the irradiated area is reduced as the primary x-ray beam is collimated to the area of interest thus, the radiation dose is minimized. All CBCT units provide voxel resolutions that are isotropic i.e. equal in all 3 dimensions whereas in case of conventional CT, the voxels are anisotropic. Sub-millimetre resolution (often exceeding the highest grade multi-slice CT) is

produced by this isotropic voxel resolutions ranging from 0.4 mm to as low as 0.125 mm. The other advantage is rapid scan time as CBCT acquires all basis images in a single rotation and comparable with that of medical spiral MDCT systems.¹⁰

The suggested use of CBCT in implant dentistry ranges from preoperative analysis with regard to specific anatomic considerations, site expansion using grafts, software-assisted treatment planning to postoperative assessment in consideration to complications caused by neurovascular structure damage.¹⁶ CBCT scans should be taken after taking thorough medical and dental histories along with performing a clinical examination.¹⁷ Effective doses for various CBCT devices reveal a wide range with the lowest being approximately 100 times less than the highest dose. Significant dose reduction can be obtained by adjusting various operating parameters such as reducing the field of view to the actual area of interest and exposure factors.¹⁶ Benavides E et al¹⁷ systematically reviewed literature regarding CBCT and implant dentistry and supported the application of CBCT in planning treatment in dental implant particularly in regards to three-dimensional evaluation of alveolar ridge topography, linear measurements, proximity to vital anatomical structures as well as fabrication of surgical guides.

Implant software

Computer software, when used with CT and CBCT, has proven to be of great value in implant diagnosis and treatment planning. Using these software programs, near-original 3D images can be obtained along with the construction of surgical templates to transfer necessary information to the patient's mouth. Generally, this procedure is based on stereolithographic models. A 3D image is created by processing the CT data in the DICOM 3 format for accurate treatment planning in implant placement.² Various implant softwares are described below.

Sidexis (Sirona Galileos)

Galileos Implant software due to color visualization of the nerve canal and the depiction of the bones in all dimensions, helps evenbeginners through the implant planning process efficiently. The implant can be ideally adapted to fit the patient's anatomy and thus, stress is minimized through precise planning and implementation.¹⁸

Planmeca Romexis

Planmeca Romexis helps in planning treatment and evaluation of implant placement using realistic implant, abutment and crown models. This software thus allows to import and superimpose a soft-tissue scan and crown design with CBCT data for implant planning.¹⁹

Anatmage invivo 5 (Gendex)

Cone Beam 3D scans acquired with Gendex 3D imaging system assist in the treatment planning process by providing clinical information. The Invivo 5 software enhances the data and provides control to design crowns, abutments and implants from Cone Beam 3D scan. It provides the tools for a restorative driven implant planning. The open interface of the software allows to import STL files making it possible to bring in digital impressions generated by intraoral scanner. The obtained digital impressions can be combined with CBCT data and while including the original bite registration from the intraoral scan, images can be paired together in the correct position.²⁰

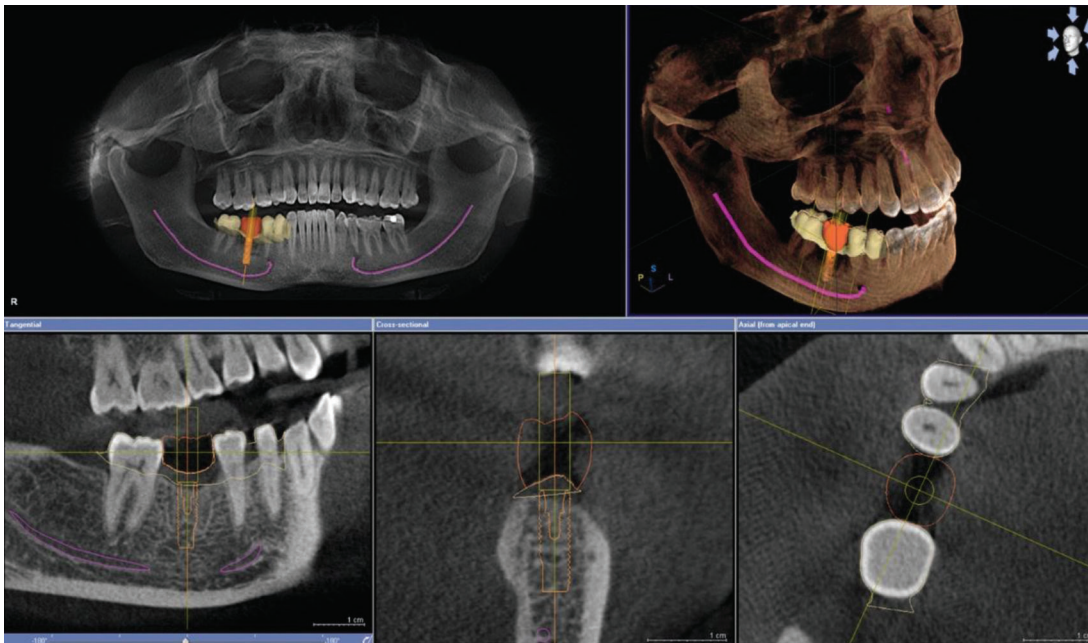


Figure-1: Sidexis (Sirona Galileos) Implant planning software



Figure-2: Planmeca Romexis Implant planning software

Veraviewepocs 3D (J. Morita 3D Accuitomo)

Veraviewepocs 3D R100 is useful for planning implant treatment with full arch imaging, clarity and low dose to the patient. It creates cross sectional images of the dental arch and highlights the mandibular canal for measuring the distance to the implant, easier viewing and determining its buccal and lingual position. A high resolution volume image of the entire jaw can be obtained which offers an easy explanation of the implant treatment process to the patient.²¹

CS9300 3D (Carestream Kodak)

CS9300 3D (Carestream Kodak) provides greater flexibility and the ability to collimate the field of view to adjust according to patients diagnostic need. The recommended fields of view for implantology of CS 9300 are 10 cm x 5 cm, 10 cm x 8 cm and 10 cm x 10 cm.²²

The computer guided implant planning helps in visualising the anatomical structures in three spatial planes. The various other programs, such as Implametric®, SimPlant®, Nobel Guide®, med3D®, etc., surgical templates can be made for selective

implant placement. Surgical navigation systems such as RoboDent®, DenX IGI®, VISIT®, CADImplant®, LITORIM®, Virtual Implant®, Vector Vision®, etc are currently able to offer greater security of critical structures to obtain improved results.²

CONCLUSION

CBCT imaging offers clinicians high diagnostic quality images with sub-millimetre spatial resolution with relatively short scanning times and a reported radiation dose equivalent to that needed for 4 to 15 panoramic radiographs.¹⁰ The factors to be considered for pre-implant imaging are radiation dose, cost of each examination and the probable information that may be provided by the imaging study. Even though many modalities are available for the implant site imaging, the technique should be adopted according to the case and the clinician’s ability to interpret the image acquired.

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