Review Article

University J Dent Scie 2024; Vol. 10, Issue 3

Diagnostic Imaging and Techniques in Implant Dentistry: A Review

Abstract:

The ultimate goal of dental implant therapy is to satisfy patient's desire to replace one/ more missing teeth in an esthetic, secure, functional and long lasting manner. Techniques of imaging and their accurate interpretation in implant dentistry are a very important and crucial step for successful treatment. Various types of radiographic images are used for diagnosis and treatment planning of dental implant patients. Options ranges from standerd projections eg. Intraoral (periapical, occlusal), extraoral (panoramic, lateral cephalometric) radiographs, routinely available in the dental office to more complex radiographic techniques eg. Conventional x-ray tomography(CT) and cone beam computed tomography (CBCT), typically available only in radiographic centers. This article discusses an advanced imaging procedures for implant with their advantages and disadvantages when compared with conventional imaging techniques.

Key-words: Dental Implant, Cone Beam Computed Tomography, Magnetic Resonance Imaging, Lateral Cephalometrics.

Introduction:

Diagnostic imaging and techniques help to develop and implement a cohesive and comprehensive treatment plan for the implant team and the patient. The decision of when to image along with which imaging modality to use depends on the integration of these factors and can be organized into three phases. [1-3]

Phase one is termed *pre-prosthetic implant imaging* and involves all past radiologic examinations along with new radiologic examinations chosen to assist the implant team in determining the patient's final and comprehensive treatment plan. The next phase is surgical and interventional phase of clinical implant imaging, and is focused on the assistance in the surgical and prosthetic interventions of the patient. Phase three is termed *post-prosthetic implant imaging.* It commences just after the prosthesis placement and continues as long as the implants remain in the jaws.[2]

Imaging modalities:

The most optimal imaging modality was used to image the patient based on the particular clinical need. The study showed that this technique was effective in terms of disease detection & diagnosis and it results in the least radiologic risk. Some of the imaging modalities that have been reported as useful for dental implant imaging include, Periapical radiography, Panoramic radiography, Occlusal radiography, Cephalometric radiography, Tomography, Computed tomography, Magnetic resonance imaging, Interactive computed tomography.

The aforementioned imaging modalities can be further divided into three different types: quasi-three dimensions, three dimensions, and planar two dimensions. Two-

Access this article online	
Website: www.ujds.in	Quick Response Code
DOI: https://doi.org/10.21276/ujds.2024.10.3.22	

[1]BRIJ KUMAR, [2]PREMKISHORE K, [3]LUMBINI PATHIVADA, [4]ANIL PANDEY

[1-3]Department of Pedodontics and Preventive Dentistry, Rungta College of Dental Sciences and Research, Bhilai, Chhattisgarh

[4]Government Dental College, Raipur, Chhattisgarh

Address for Correspondence: Dr. Brij Kumar
Reader, Department of Pedodontics and Preventive Dentistry, Rungta College of Dental Sciences and Research, Bhilai, Chhattisgarh, India
Email : brij220787@gmail.com

Received : 7 January, 2023, **Published :** 30 Sept., 2024

How to cite this article: Brij Kumar, Premkishore K, Lumbini Pathivada, & Anil Pandey. (2024). Diagnostic Imaging and Techniques in Implant Dentistry: A Review . UNIVERSITY JOURNAL OF DENTAL SCIENCES, 10(3).

dimensional imaging modalities include dental periapical bite wings, occlusal and cephalometric imaging. These imaging techniques project a two-dimensional picture of the patient's anatomy. These images cannot provide a satisfactory evaluation of the three-dimensional nature and morphology of the patient's anatomy. Quasi three-dimensional imaging modalities include x-ray tomography and some cross sectional panoramic imaging techniques.[3-5]

Computerized tomography (CT), Cone Beam Computed Tomography (CBCT) and magnetic resonance imaging (MRI) images are examples of three dimensional imaging techniques which enable the clinicians to recognize 3-D images of a patient's anatomy. Most of the dentists use analog, two-dimensional imaging**.** Analog imaging modalities are two-dimensional systems that employ x-ray film and/or intensifying screens as the image receptors.[4]

With any of the aforementioned imaging modalities, digital images can also be created. A two-dimensional digital image is represented by an image matrix made up of discrete picture components known as pixels. A digital image's pixels, width, and height are used to describe it (i.e., 512 by 512). For larger digital image (i.e., 1.2M by 1.2M [M= megapixel]), the image is alternatively described as a 1.5 megapixel image. Each component of a picture, or "pixel," has a discrete digital value that specifies the intensity of the image at that specific location. A scale that can range from 8 bits (256 values) to 12 bits (4096 values) for black-and-white imaging systems or 36 bits (65 billion values) for colour imaging systems is used to describe the value of a pixel element. A dedicated black and white monitor is the best display option for digital black and white images. On a monitor, 8 bits or 256 levels can typically be successfully represented. An image matrix with discrete image/picture components known as voxels serves as the description for a digital three-dimensional image. A digital three-dimensional image is described not only by its width and height and pixels (i.e., 512 by 512), but additionally, by its depth/thickness.[4,5]

Preprosthetic imaging:[6]

The goal of this phase of implant imaging is to assess the condition of the patient's teeth and jaws as well as to establish and improve the patient's treatment plan.

The specific objectives of preprosthetic imaging are to,

1. Identify disease
4. Identify critical structures at the proposed implant regions
5. Determine the optimum position of implant placement relative to occlusal loads.

Periapical radiography:

Images of a specific area of the mandibular or maxillary alveolus are captured on periapical radiography. Periapical radiographs are made by inserting the film intraorally parallel to the body of the alveolus and aligning the region of interest with the central ray of the x-ray device to create a lateral view of the alveolus. Periapical radiographs only show the jaws from the side and do not show their cross sections.

Periapical radiographs may exhibit both magnification and distortion. The long cone paralleling technique will eliminate distortion and limit magnification to less than 10%. Burn out effects are common when standard kV and mA are used, making crestal bone loss with digital intraoral systems of benefit in these situations.[6-8]

Occlusal radiography:

Occlusal radiographs are planar radiographs generated by inserting the film intraorally parallel to the occlusal plane and aligning the central x-ray so that the mandibular image is perpendicular to the film and the maxillary image is oblique (often 45 degrees) to the film. High-resolution planar images of the maxilla or mandible's body are created using occlusal radiography. Maxillary occlusal radiographs are inherently distorted and oblique, making them useless for quantifying the geometry or level of mineralization of the implant site in implant dentistry. Additionally, critical structures such as the maxillary sinus, nasal cavity and nasal palatine canal are demonstrated but the cavity, and nasal palatine are demonstrated, but the spatial relationship to the implant site is generally lost with this projection.[6]

Cephalometric radiographs:

Oriented planar radiographs of the head are commonly known as cephalometric radiographs. This radiograph shows a cross sectional view of the alveolus of the mandible and the maxilla in the midsagittal plane. The lateral incisor or canine areas can also produce a cross-sectional image of the mandible or maxilla with a small rotation of the cephalometer. The lingual plate's relationship to the patient's skeletal structure and the geometry of the anterior alveolus are both seen on the lateral cephalometric radiograph, which is helpful.

The width of bone in the symphysis region and the relationship between the buccal cortex and the roots of the anterior teeth may also be determined before harvesting this bone for ridge augmentation. Together with regional periapical radiographs, quantitative spatial information is available to demonstrate the geometry of the implant site and spatial relationship between the implant site and the spatial relationship between the implant site and important tissues like the nasal palatine canal's floor. Additionally, the lateral cephalometric view can assess a loss of vertical dimension, the relationship between the skeletal arches, the anterior crown implant ratio, the position of the anterior teeth in the prosthesis, as well as the moment of forces that results.[7-8]

Panoramic radiography:

Panoramic radiography is a curved plane tomographic radiographic technique used to depict the body of the mandible, maxilla and the lower one half of the maxillary sinuses in a single image.

Advantages of Panoramic radiography:

1. Opposing landmarks are easily identified.
2. It makes possible to determine the bone's initial vertical height.
3. In the majority of dental offices, the process is completed quickly, conveniently, and easily.
4. Gross anatomy of the jaws and any related pathology findings can be evaluated.

Disdvantages Panoramic radiography:

1. Does not demonstrate bone quality/ mineralization
2. Is misleading quantitatively because of magnification and because the third dimension, cross-sectional view, is not demonstrated
3. Is of some use in demonstrating critical structures but of little use in depicting the spatial relationship between the structures and dimensional quantitation of the implant site.[8],

Tomography:

A generic word "tomography," is derived from the Greek terms "tomo" (slice) and "graph" (picture). Body section radiography is a specialised x-ray method that makes it possible to see a specific area of the patient's anatomy by obscuring areas of the patient's anatomy above and below the area of interest.

There are numerous inventive tomographic techniques and equipment. The x-ray tube and film are nevertheless joined by a rigid bar called the fulcrum bar, which pivots on a point known as the fulcrum, in accordance with the fundamental concept of tomography. When the system is turned on, the film plane moves in the opposite direction from the x-ray tube, and the system pivots around the fulcrum. The fulcrum remains stationary and defines the section of interest, or the tomographic layer.

High-quality complex motion tomography shows the alveolus in dental implant patients, and when magnification is taken into account, it enables assessment of the alveolus' geometry. The spatial link between the crucial structures and the implant site can also be determined using this technique. The ideal tomographic sectioning strategy would allow for examination of the implant site region and, with mental integration, understanding of the alveolus's nearly three-dimensional appearance. Compensation for magnification can be used to estimate the amount of alveolar bone that is accessible for implant insertion. Tomographic implant pictures that have undergone post-imaging digitization can now be used with a digital ruler to help determine how much alveolar bone is available for implant placement. Image enhancement can aid in identifying critical structures such as the inferior alveolar canal.[11,14,15]

Computed tomography:

The digital and mathematical imaging technology known as computed tomography (CT) produces tomographic sections without the interference of blurred structures from surrounding anatomy.

Computed tomography also allows for the identification and quantification of both soft and hard tissues, which is likely most significant.

Sir Hounsfield developed the CT and introduced it to the imaging industry in 1972.

CT images are inherently three dimensional digital images typically 512 by 512 pixels with a thickness described by the slice spacing of the imaging technique.12,13]

Interactive computed tomography:

Using this method, the radiologist can send the imaging study to the doctor as a computer file so that the doctor can view it and interact with it on their personal computer. The clinician's computer transforms into a diagnostic radiologic workstation with tools to quantify the alveolus' length and width, the quality of the bone, and to alter the study's window and level of grayscale to improve the visibility of important structures.

ICT's ability to do "electronic surgery" (ES) by choosing and positioning arbitrary size cylinders that stimulate root form implants in the images is a key feature.

With an appropriately designed diagnostic template, ES can be performed to electronically develop the patient's treatment plan in three dimensions.[15,18,19]

Magnetic resonance imaging:

Other than computed tomography, magnetic resonance (MR) imaging is one of the most advanced and revolutionary medical imaging techniques. MRI is a type of imaging that uses a magnetic field, radio frequencies, electromagnetic detectors, and computers to create images of the body's protons. The technique was first announced by Lauterbur in 1972.

For high resolution imaging acquisitions, digital MR images are distinguished by voxels with an in-plane resolution measured in pixels (512 by 512) and millimetres, as well as section thickness measured in millimetres (2 to 3 mm).

In implant imaging, MR is utilised as a secondary imaging method when primary imaging methods such complex tomography, CT, or ICT don't work. Complex tomography fails to differentiate the inferior alveolar canal in 60% of implant cases and CT fails to differentiate the inferior alveolar canal in approximately 2% of implant cases. Osteoporotic trabecular bone and a weakly corticated inferior alveolar canal may be a reason for the inability to recognize the inferior alveolar canal. The inferior alveolar canal and neurovascular bundle are distinguished from the surrounding trabecular bone by MR, which also shows fat in the trabecular bone. MR is not useful in characterizing bone mineralization or for identifying bone or dental disease.[16,17,18]

Diagnostic templates:

By using diagnostic radiographic templates, the planned course of treatment for the patient can be incorporated into the radiographic examination. This requires that a treatment plan be developed prior to the imaging procedure.

The pre-prosthetic imaging procedure enables evaluation of the proposed implant site at the ideal position and orientation identified by radiographic markers incorporated into the template.13,15

Computed tomography:

The use of comprehensive and accurate diagnostic templates is made possible by the precision of CT. The prosthesis is oftenly what determines the precise length and orientation of the implant, which frequently determines its actual size. As a result, an imaging-based diagnostic template is quite helpful. The diagnostic CT template should include the surfaces of the suggested restorations as well as the precise location and orientation of each dental implant.

There are two diagnostic templates, one created from a processed acrylic reproduction of the diagnostic wax-up and the other from a vacuform reproduction of the diagnostic wax-up.

By applying a thin layer of barium sulphate to the intended restoration and filling a hole drilled through the occlusal surface of the restoration with gutta percha, the processed acrylic template is transformed. The surfaces of the intended restoration then turn radiopaque in the CT scan, allowing the positioning and orientation of the proposed implant to be determined. The proposed restoration contains a radiopaque gutta percha plug.

The vacuform template has a number of variations. One design involves coating the proposed restorations with a thin film of barium sulfate. Another design involves filling the proposed restoration sites in the vacuform of the diagnostic wax up with a blend of 10% barium sulfate and 90% cold cure acrylic. As a result, the proposed restorations appear as radiopaque teeth in the CT scan.

Tomography:

In comparison to CT scans, diagnostic templates for tomography examinations are typically less reliable. The diagnostic data obtained from tomography examinations is not as thorough or accurate as that obtained from CT scans. To create the simplest tomography template, a 3-mm vacuform of the patient's diagnostic cast is taken. ball bearings are inserted at the suggested implant sites. The implant site is detected by the tomogram with the ball bearing in great focus among several tomograms of the implant region.

The ball bearing can additionally serve as a measure of the magnification of the imaging system Templates that incorporate metal cylinder or tubes at the proposed implant sites also enable evaluation of tomograms for the orientation along with the position of the proposed implant.[18,19,20,21]

Surgical templates:

Surgical templates can be created using diagnostic templates. If metamorphosis from diagnostic template to surgical template is the objective of the surgeon, the diagnostic template should be selected and fabricated with that in mind.

CAD CAM stereotactic surgical templates:

Several CAD-CAM and rapid prototyping techniques can be used to create three-dimensional representations of the patient's alveolar anatomy that are anatomically precise.

From interactive CT scans that were used to create a three-dimensional treatment plan for the patient for the position and orientation of dental implants, CAD-CAM surgical stereotactic templates can be created.

A stereotactic surgical template is derived from the model by aligning guide cylinders at the implant sites, which just accommodate a pilot drill, and producing a vacuform using surgical template material of the model and guide cylinders. As a result, a plastic surgical template is created that precisely replicates the location and orientation of the suggested implants while also adapting and conforming to the bony anatomy of the patient.[19-21]

Surgical and Interventional imaging:

Imaging the patient during and after surgery, as well as when the prosthesis is being placed, is a part of surgical and interventional imaging. The purpose of surgical imaging is to evaluate the depth of implant placement, the position and orientation of implants/osteotomies, and to evaluate donor or graft sites.[20,21]

Post-prosthetic imaging:

Post prosthesis implant imaging is used to assess the condition and prognosis of the dental implant. Regular assessments of the bone volume or mineralization in the area around the dental implant are recommended. Inflammation, infection, high axial or shear stress, bone deterioration from implant site, lack of integration with an epithelial bone implant interface might be causes for the loss of cylindrical bone volume adjucent to the implant surface .[18,20,21]

Periapical radiography:

Only the mesial, distal, inferior, and crestal aspects of the implant are shown, together with the implant bone contact when the central ray of the x-ray source is tangential to the implant surface. This modality does not adequately represent other areas of the implant interface.

Bite-wing radiographs:

Intraoral radiographs are the best tool for evaluating both the short- and long-term evaluation of crestal bone loss surrounding implants. Threaded implants make it simpler to read the criteria of marginal bone loss. Before the threads start, the crestal region of the majority of threaded implants is smooth and ranges in size from 0.8 to 2 mm, depending on the manufacturer. Once the threads start, the pitch is constant (distance between the threads). By comparing the current implant placement to the original implant placement and the initial radiograph of the prosthesis makes possible to calculate the amount of crestal bone loss. The image is optimal when the implant body threads can be seen clearly on both sides.[16,18,19]

Temporal digital subtraction radiography:

A radiographic technique called temporal digital subtraction radiography (SR) allows for the subtraction of two radiographs of the same anatomic region taken at various times, producing an image of the difference between the two original radiographs. The resulting subtraction image shows changes in the patient's anatomy that occurred between the two radiographs, such as alveolar mineralization or volume alterations. Alveolar bone can be shown to have buccal and lingual changes in addition to mesial and distal changes using SR.

SR has had limited utilization in clinical practice because of the difficulty in obtaining reproducible periapical radiographs.[21,22]

Conclusion:

There are numerous radiographic projections that can be used to assess implant placement, each with pros and cons. The clinician must follow the sequential steps in patient evaluation and radiography is an essential diagnostic tool for implant design and successful treatment of the implant patient.

References:

1. Jayadevappa BS, Kodhandarama GS, Santosh SV, Rashid WT. Imaging of dental implants. J Oral Health Res 2010;1:50-61.
2. Frederiksen NL. Diagnostic imaging in dental implantology. Oral Surg Oral Med Oral Pathol Oral Radiol Endod 1995;80:540-54.
3. Nagarajan A, Perumalsamy R, Thyagarajan R, Namasivayam A. Diagnostic imaging for dental implant therapy. J Clin Imaging Sci 2014;4:4
4. Michael J. Engelman et al. Optimum placement of osseointegrated implants. J Prosthet dent 1988:59:4:467-473.
5. Harold P. Truitt et al. Non invasive technique for mandibular subperiosteal implant. A preliminary report. J Prosthet Dent. 1986:44:494-7.
6. Ramuald J. Fernadez et al. A cephalometric tomographic technique to visualize the buccolingual and vertical dimensions of the mandible. J Prosthet Dent 1987:58:466-470

7. Devg C. Magnetic resonance imaging in patients with dental implants. A clinical report. IJOMI 1997: 12:3:354-359

8. Lam E.W Reprecht and Yang. Comparison of two dimensional orthoradially reformatted computed tomography and panoramic radiography for dental implant treatment planning. J Prosthet Dent 1995:74:42-46.

9. AW Lawrence. CT scan as a radiologic data base for optimum implant orientation. J Prosthet Dent 1993: 69: 381-385

10. Almog, Rodolfo Sanchez. Correlation between planned prosthetic andresidual bone trajectories in dental implants. J Prosthet Dent 1999: 81:5: 562.

11. Modica, et al. Radiologic prosthetic planning of the surgical phase of the treatment of edentulism by osseointegrated implants. An invitro study. J Prosthet Dent 1991:65:541-546

12.Along D. Fabrication of imaging and surgical guides for dental implants. J Prosthet Dent 2001:85:504-508.

13. Kopp KC, Koslow AH, Abdo OS. Predictable implant placement with a diagnostic/surgical template and advanced radiographic imaging.) J Prosthet Dent. 2003 Jun;89(6):611-5.

14. Siu AS, Li TK, Chu FC, Comfort MB, Chow TW. The use of lipiodol in spiral tomography for dental implant imaging. Implant Dent. 2003;12(1):35-40.

15. Basten CH. The use of radiopaque templates for predictable implant placement. Quintessence Int. 1995 Sep;26(9):609-12

16. Aryatawong S, Aryatawong K. Evaluation of the inferior alveolar canal by cross-sectional hypocycloidal tomography. Implant Dent. 2000;9(4):339-45.

17. Tan KB. The use of multiplanar reformatted computerised tomography in the surgical-prosthodontic planning of implant placement.) Ann Acad Med Singapore. 1995 Jan;24(1):68-75.

18. Siddiqui AA, Caudill R, Beatty K. Use of an optical comparator for radiographic measurement of bone loss around endosseous implants: a pilot study. Implant Dent. 1995 Summer;4(2):85-8.

19. Ludlow JB, Nason RH Jr, Hutchens LH Jr, Moriarty J. Radiographic evaluation of alveolar crest obscured by dental implants. Implant Dent. 1995 Spring;4(1):13-8.

20. Gray CF, Redpath TW, Smith FW. Pre-surgical dental implant assessment by magnetic resonance imaging. J Oral Implantol. 1996;22(2):147-53.

21. Takeshita F, Suetsugu T. Accurate presurgical determination for implant placement by using computerized tomography scan. J Prosthet Dent. 1996 Dec;76(6):590-1.

22. Cehreli MC, Aslan Y, Sahin S. Bilaminar dual-purpose stent for placement of dental implants. J Prosthet Dent. 2000 Jul;84(1):55-8.