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Radiological Aspects of Dental Implants: A Narrative Review

Syed Sayeed Ahmed, M. Ranjith Kumar*, Ghulam Sarwar Hashmi

Abstract

Dental implant technology has undergone dramatic changes in the past few years and has become a significant treatment planning option in restorative dentistry. Dental implants have become an accepted form of permanent tooth replacement. Diagnostic imaging can play an important role in evaluating patients with such implants. Useful imaging studies include panoramic radiography, computed tomography, and computer-reformatted cross-sectional, panoramic, and three-dimensional imaging. Advanced imaging studies can be used to determine the suitability of implant placement, appropriate sites for implant placement, the size of the implant that can be placed, and the need for pre-implantation ridge surgery. This review article summarizes various radiological diagnostic imaging of implants.

Keywords: Dental implants, Diagnostic imaging, Restorative dentistry, Three dimensional imaging

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Introduction

The objectives of diagnostic imaging depend on number of factors including the amount and the type of information required and the time period of the treatment rendered.[1] Several imaging modalities have been used for pre surgical evaluation of implant sites. No single radiographs procedure provides ideal images for all the steps in implant planning process. Increasingly, however, computed tomography (CT) is being regarded as the modality of choice for detailed planning before surgery itself. The production of reformatted cross-sectional and panoramic images presented life size on an X-ray film or as a booklet of photographic quality prints has been long established. Today more than ever a plethora of imaging modalities is available for dentists who is complaining implant therapy for his patients.[2-5]

Need for Imaging Evaluation for Implants

Pre-operative[1,3,6]

During the pre-operative stage, implant imaging can be used to determine.

- Position and size of relevant normal anatomical structures
- Shape and size of antrum
- Presence of underlying bone disease
- Presence of retained roots or buried teeth
- Quality of alveolar bone allowing direct measurement of height, width, and shape
- Quality/density of bone
- Amount of cortical bone left
- Density of cancellous bone
- Size of trabecular spaces.

Post-operative

During the post-operative stage, implant imaging can be used to determine

- Position of fixture in the bone and its relation to nearby anatomic structure
- Healing and integration of fixture in the bone
- Peri implant bone level and any subsequent vertical bone loss
- Development of any associated disease-peri-implantitis
- Fit of abutment to fixture
- Fit of abutment to crown/prosthesis
- Possible fracture of implant prosthesis.

Department of Oral and Maxillofacial Surgery, Faculty of Medicine, Aligarh Muslim University, Aligarh, Uttar Pradesh, India

Corresponding Author: Dr. M. Ranjith Kumar, Department of Oral and Maxillofacial Surgery, Faculty of Medicine, Aligarh Muslim University, Aligarh, Uttar Pradesh, India. Phone: 7418787042. E-mail: rkranjith.29@gmail.com

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Objectives of Imaging

The objectives of diagnostic imaging depend on number of factors including the amount and the type of information required and the time period of the treatment rendered. The decision whether to image alone or with additional imaging modality depends on the integration of these factors and can be organized into three phases.[1,3]

Phase one is termed as pre prosthetic implant imaging and involves all past radiological examination chosen to assist the implant team in determining the patient's final and comprehensive treatment plans.

The objective of this phase of imaging includes:

- All necessary surgical and prosthetic information to determine the quality, quantity, and the angulations of bone
- The relationship of critical structures to prospective implant sites and
- Presence or absence of disease at the proposed surgical site.

Phase two is termed as surgical and interventional imaging and is focused on assisting in the surgical and prosthetic intervention of the patient.

The objective of this phase of imaging includes:

- To evaluate the surgery sites during and immediately after surgery

- To assist in optimal position and orientation of dental implants
- Evaluate the healing and integration phase of implant surgery and
- Ensure abutment position and prosthesis fabrication are correct.

Phase three is termed post-prosthetic imaging. It commences just after the prosthesis placement and continues as long as the implants remain in the jaws.

The objective of this phase of imaging includes:

- To evaluate the long-term maintenance of implant rigid fixation and function including the crestal bone levels around each implant and
- To evaluate the implant complex.

Principles Guiding the Selection of the Imaging Technique

There are number of basic principles of radiography that should guide the clinician in selecting an appropriate imaging technique and judging whether the resultant images are of adequate quality for the purpose.[1]

- First, there should be adequate number and type of images to provide the needed anatomic information. In implant planning, for example, this information includes the quantity and quality of bone, as well as the location of anatomic structures, which generally requires multiple images right angles to each other.
- Second, the type of imaging technique selected should be able to provide the required information with adequate precision and dimensional accuracy. Use of technique that will allow accurate repositioning of patient such as with a cephalostat is also helpful in comparing pre-operative and post-operative images.
- Third, there must be a way of relating images to the patient anatomy.

For edentulous regions of the jaw, this, generally, earns the use of stent with radiographic markers during imaging. The exact location of the longitudinal and cross-sectional views can thus be determined with respect to edentulous mandible or maxilla.

- Fourth, in whatsoever technique used, the patient X-ray beam and imaging receptor should be positioned to minimize distortion. In addition, all images should be free from adequate density and contrast and should be free from artifacts that might interfere with interpretation.

Finally, the desire for pre-operative imaging information should be balanced with the radiation dose and financial cost to the patient. The ALARA principle[7] should govern the principle if more than one technique is feasible.

Basic Principles to Follow during Implant Imaging[1]

The American academy of Oral and Maxillofacial Radiology recommends that the dentist or radiologist should complete the following steps in conducting a conventional tomographic implant imaging examination:

1. Take an appropriate scout film (panoramic or occlusal, depending on the tomographic equipment) to aid in selecting imaging planes and angles.
2. Verify implant sites using stents with radio-opaque indicators, preferably based on diagnostic wax-ups.
3. Use beam indicating lights and cephalostats as appropriate for the specific equipment.
4. Orient the cross-sectional images perpendicular to the desired region of jaw bone.
5. Obtain longitudinal or parasagittal images along with the cross-sectional images so that cross relation is possible.
6. Write a complete report with tracings, measurements, or both for each patient.

For CT imaging the referring dentist should communicate thoroughly with the radiologist (medical or oral and maxillofacial) and ensure that the patient is positioned appropriately (0 degree gantry angle) that a stent with radiopaque markers (gutta-percha) is used and that the scan plane is parallel to the occlusal plane. In all the cases, collaboration with the restoring dentist is paramount.

The Various Techniques Include

- Periapical radiographs – conventional and digital
- Occlusal radiographs
- Panoramic radiographs
- Lateral cephalogram
- Zonography
- Tomography
- Cross sectional linear tomography
- Multi directional linear tomography
- TACT
- CT
- Multiplanar CT
- MRI.

The imaging modalities can be described as either analog or digital and two-dimensional or three-dimensional.

Periapical Radiographs

The paralleling technique described by McCormack for teeth in 1920 should be used when obtaining periapical radiographs. The procedure is modified so the X-ray film is positioned parallel to the final implant position. This technique minimizes geometric distortions, provide better resolution, and procedures anatomically truer images.[8]

Digital Radiography[3]

It is an imaging process wherein the film is replaced by the sensor that collects the data. The analog information received is then interpreted by specialized software and an image is formulated on a computer monitor. The resultant image can be modified in various ways such as gray scale, brightness, contrast, and inversion.

Occlusal Radiographs

An occlusal projection is intraoral radiographic technique used to visualize the maxilla and mandible. The film is intraorally placed and the patients head is rotated so that the film is at right angle to the floor. The primary beam is then directed at right angles to the film to provide a cross sectional image.[8]

The buccolingual width of mandible depicted on an occlusal film is the distance between the points located on extreme boundaries of buccal and lingual cortical plates, but not necessarily in the horizontal plane. For this reason, occlusal radiographs are of very limited use in implant dentistry.[3,8]

Lateral Cephalograph

A lateral cephalograph or skull projection may be used as a tomogram, or section of the midsagittal region of the maxilla and mandible. The magnification ranges from 6% to 15% and provides a more accurate representation than panoramic radiographs of vertical height, width, and angulation of bone at the midline. In addition, a lateral projection of the skull can help evaluate a loss of vertical dimension, skeletal arch interrelationship, anterior crown-implant ratio, anterior tooth position in the prosthesis, and resultant moment forces.[8,9]

Panoramic Radiographs

Panoramic radiographs are a part of the standard of care for pre-operative evaluation of an implant site, as well as for the longitudinal assessment of the success of the implant.[1]

The panoramic radiograph produces a single image of the maxilla and mandible and their supporting structures in a frontal plane. This type of radiograph is the most utilized diagnostic element in implant dentistry today.[3]

Zonography

Recently, a modification of the panoramic X-ray machine has been developed that has the capability of making a cross-sectional image of the jaws.[10] Different types of motion of the X-ray tube and film are Employed-Linear (the simplest), circular, trispiral, elliptical, and hypocycloidal.[10]

This technique enables the appreciation of spatial relationship between the critical structures and the implant site.[10] It is particularly useful when subject contrast is low due to little difference in physical density between adjacent structures.[10]

Tomography

It is designed to image more clearly objects lying within a plane of interest. It is accomplished by blurring the images of structures lying superficial and deep to the plane of interest through the process of motion "unsharpness."[3]

The diagnostic quality of the resulting tomographic image is determined by the type of tomographic motion, the section thickness, and the degree of magnification. The type of tomographic motion is probably the most important factor in tomographic quality.[3]

Post-imaging digitization of tomographic implant images enables use of a digital ruler to aid in the determination of alveolar bone for implant placement. Image enhancement can aid in identifying critical structures such as the inferior alveolar canal.[3]

Reformatted/Multiplanar CT[9,11]

Three-dimensional radiographic imaging was first conceived in the early 20th century and was proved by calculating an infinite number of projections of the image of a three-dimensional object.

Dentascan Imaging[3]

Dentascan imaging provides programmed reformation, organization, and display of the imaging study. The radiologist or technologist simply indicates the curvature of the mandibular or maxillary arch and the computer is programmed to generate referenced cross-sectional and tangential/panoramic images of the alveolus along with three-dimensional images of the arch. The cross-sectional and panoramic images are spaced 1mm apart and enable accurate pre-prosthetic treatment planning.

Interactive CT[3,11]

This technique enables the radiologist to transfer the imaging study to the clinician as a computer file and enables the clinician to view and interact on their own. With the imaging study clinicians' computer becomes a diagnostic radiologic work station with tools to measure the length and width of the alveolus, measure bone quality, and change the window and level of the gray scale of the study to enhance the perception of critical structures.

Cone Beam CT[12-14]

It is relatively newer modality. CBCT scanners are based on volumetric tomography, using 2D extended digital array providing an area detector. This is combined with a 3D X-ray beam.

Cone Beam Volume Tomography (CBVT)

It is a method to produce volume imaging quicker and easier than conventional CT. the technology has been used to design CBVT systems specifically for dental imaging. This two basic principle differences that distinguish CBVT from traditional CT are the type of imaging source detector complex and the method of data acquisition.[15]

Magnetic Resonance Imaging

MR is an imaging technique used to image the protons of the body by employing magnetic fields, radio frequencies, electromagnetic detectors, and computers.[16,17] MR is used in implant imaging as a secondary imaging technique where primary imaging techniques such as complex tomography, CT, or ICT fail.

Periapical Radiography[3]

The implant bone interface is depicted only at the mesial, or distal, and crestal aspects or, where the central ray the X-ray source is tangent to the implant surface. Other regions of the implant interface are simply not depicted well by this modality.

Digital Periapical Radiography[3]

Digital radiographs can be subjected to image processing with which the images can be altered to achieve task specific image characteristics. For example, density and contrast can be lowered for evaluations of marginal bone and increased for evaluations of implant components.

Bite-wing Radiographs[3]

Quality bitewing radiographs placed parallel to the implant body with the central ray of source oriented perpendicular to the film enable sequential radiographs for crestal and per-implant bone loss.

Table 1: Summary review

Imaging modality	*Applications*	*Cross-sectional information*	*Advantages*	*Disadvantages*
PA radiography	SI, MI, RA, E	Not provided	Easily available, greater resolution, cost effective, less distortion, low dose	Limited area imaging,Facio-lingual dimension not recorded,limited reproducibility, image distortion
Occlusal radiography	SI, MI, RA	Not provided	Easy availability, high image definition, relatively large imaging area, low cost, low dose	Image superimposition, not much information on buccolingual dimension, less use in maxilla limited reproducibility
Panoramic radiography	SI, MI, RA, E	Not provided	Easy availability, minimal cost,large imaging area, low dose	Buccolingual dimension not provided, image distortion present, technique errors are common, inconsistent horizontal magnifications
Conventional tomography	SI, MI, RA, E	Provided	Minimal image overlap, low to moderate dose, provides buccolingual information, Simulates implant placement with use of software, Moderate cost, Accurate measurements	Technique sensitive, Limited availability, Less image resolution than plain film, requires trained personnels
Computed tomography	SI, MI, RA, E	Provided	Information on all sites are available, No superimposition, uniform magnification, Accurate measurements Simulates implant placement with use of software, Makes interpretation more reliable and minimizes inter operator interpretation errors	Technique sensitive, limited availability, special training required, high cost high doses
Cone beam computed tomography	SI, MI, RA, E	Provided	Better image resolution Lower dose than CT Lower cost than CT simulates implant placement with use of software easy availability compact equipment images with better resolution minimal distortion and magnification makes interpretation more reliable and minimizes inter operator interpretation errors	Does not represent the actual gray scale value Bone density cannot be evaluated because of X-ray scattering Longer scanning time
Tuned aperture computed tomography	SI, MI, RA, E	Provided	Low dose cost efficient Is of greater diagnostic value contrast and resolution of image can be adjusted Accommodates patient motion between exposures	Technique sensitive limited availability special training required low quality of images
Dentascan	SI, MI, RA, E	Provided	Bone height and width is obtained Identification of soft and hard tissue pathology Anatomical structures can be located Measuring vital qualitative dimensions necessary for implant placement	Radiation exposure expensive

SI: Single implants, MI: Multiple implants, RA: Ridge augmentation, E: Edentulous ridge

Temporal Digital Subtraction Radiography[3]

Temporal digital subtraction radiography is a radiographic technique that enables two radiographs made at different points of time of the same anatomic region to be subtracted resulting in an images of the difference between the two original radiographs. The resulting subtraction image depicts changes in the patient's anatomy such as alveolar mineralization or volume changes during the time between which the two radiographs are made. SR has had limited utilization in clinical practice because of the difficulty in obtaining reproducible periapical radiographs.

Back Scattered Emission (BSE) Technology[18]

BSE is a method for assessing bone mineral content. BSE produces magnified, gray scale images of osseous tissue samples. The specimens' surface is bombarded with electrons, many of which are scattered back from the specimen.

Micro CT[19]

Micro CT is introduced as the probable successor to routine histological sectioning and micro radiography for assessing bone modeling and remodeling activity in mineralized tissues. This technological innovation is a major advance for assessing the supporting bone of dental implants.

Scintigraphic Methods Spect[20,21]

Bone scintigraphy is a well-established imaging technique that accurately reflects osteoblastic activity. Evaluation of bone metabolism in the peri-implant zones, provides anatomic images and functional dynamics information on the osseointegration process

Summary

The selection of imaging modalities may be made based on Table 1.[22]

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