Diagnostic Imaging For Dental Implants


ABSTRACT

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 plain 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 preimplantation ridge surgery. Postoperatively, advanced imaging studies can show failure of an endosseous implant to osseointegrate, improper placement of an implant, and violation of important structures. This paper gives a brief insight into the various imaging modalities, which have been applied in implantology. The final selection of one of these imaging modalities is dependent on the operator choice based on the patient's need.

Keywords: Implants, Radiography, Osseointegration
INTRODUCTION

Dental implants have revolutionized the field of dentistry because they not only replace lost teeth, but are also permanent restorations that do not interfere with oral function or speech or compromise the self esteem of patients. The ultimate objective of fixture placement is a fundamental esthetic and maintainable restoration for which no imaging technique is perfect with each examination carrying the risk of false negative or false positive results. Therefore, the patient's specific needs must carefully be considered. For the success of implants, a pre surgical treatment planning, intra operative assessment and post operative follow up is of utmost importance. To aid this, diagnostic imaging plays a vital role. This article gives an overview on the various imaging modalities available currently and their clinical applications.

SELECTION OF RADIOGRAPHIC METHOD

The choice of the radiographic technique appropriate for the given patient depends upon number of factors including type of implant used, position of remaining dentition and extent to which the bone quality is in question. Thus, the selection of the radiographic method depends on the following key points mentioned below:

1. There should be adequate number and type of the images to provide the needed anatomic information.
2. The type of imaging technique selected should be able to provide the required information with adequate precision and dimension accuracy.
3. In whatsoever technique used, the patients X ray beam and imaging receptor should be positioned to minimize distortion.
4. The imaging information should balance with the radiation dose and financial cost to the patient.

DIAGNOSTIC IMAGING MODALITIES

There are many imaging modalities that have been employed for the implant imaging, including devices developed specifically, for dental implant imaging. These modalities can be described as either analog or digital and two dimensional or three dimensional. Analog imaging modalities are the periapical, occlusal, panoramic, lateral cephalometric radiographs which are two dimensional systems that employ X ray film and or intensifying screens as the image receptors. Digital imaging include the Computed Tomography, Cone beam CT, MRI etc. These create a three dimensional image which is described not only by its width, height and pixels, but additionally by its depth and thickness.

Intraoral Periapical Radiography

Intraoral Periapical Radiography provides images of perhaps the greatest details of any imaging technique. (Fig:1) Using these images, the target area can be carefully examined for trabecular patterns, residual roots, peridontium, as well as angulation of adjacent teeth. However, because periapical radiographs show a two dimensional perspective of a three dimensional anatomy,
they are not adequate to estimate the amount of available bone.\(^1\) Also periapical radiography may suffer from both distortion and magnification which can be eliminated by use of paralleling cone technique. In terms of the objectives of pre-prosthetic imaging is concerned, the periapical radiography is:
  i. Useful for ruling out local bone or dental disease.
  ii. Of limited value in determining bone quantity because the image quality shows distortion.
  iii. Of limited value in determining bone mineralization
  iv. Good in identifying critical structures
  v. But of limited value in showing spatial relationship b/w the structures and proposed implant site.

**Occlusal Radiography**
Occlusal radiographs are planar radiographs. They show the widest width of bone vs the width of crest, where diagnostic information is needed the most. Also they have limited role in determining the bone mineralization and spatial relationships.\(^8\)

**Lateral Cephalometric Projection**
Cephalometric radiographs are oriented planar radiographs of the skull. These provide information of the maxillar and mandibular alveolar process in the mid sagittal plane. The geometry of cephalometric devices results in 10% magnification of image with a 60 inch focal object and 6 inch object to film distance.

The soft tissue profile is also apparent on this film and can be used to evaluate profile alteration after prosthodontic rehabilitation.\(^9\) The lateral cephalometry is useful in following ways:
  i. Demonstrates the geometry of the alveolus in the anterior region.
  ii. Relationship of the lingual plate to patient's skeletal anatomy.
  iii. Width of bone in the symphysis region.
  iv. Relationship between the buccal cortex and roots of the anterior teeth (Before ridge augmentation)

It provides more accurately the spatial relationship b/w occlusion and esthetics and gives information on inclination, height and width of alveolar bone at the midline, when compared to panoramic radiographs. It's useful for bone quantity determination however, not useful for demonstrating bone quality.\(^3\)

**Panoramic Projection**
A panoramic radiograph is a curved plane tomographic radiographic technique used to depict body of the mandible, maxilla, and the lower one half of the maxillary sinuses in a single image. This is the most utilized diagnostic modality in implant dentistry having advantages such as opposing landmarks are easily identified, vertical height of bone initially can be assessed, gross anatomy of jaw, critical structures and related pathologies (Fig:2) can be evaluated.\(^8\) It saves lot of time and is easy to perform with low radiation exposure. On the other hand it does not demonstrate spatial relationship, bone quality/
mineralization and is misleading quantitatively because of magnification errors. Therefore predetermination of the magnification factor for the target area can be accomplished by using a radiographic stent with ball bearings embedded in acrylic and imaged in the patient's mouth. (Fig: 3) The diameter of the ball bearings in the area can be measured radiographically and compared with their actual diameter.

Zonography
Recently, a modification of panoramic imaging has been developed with capability of making crosssectional images. This technique enables the appreciation of spatial relationship between the critical structures and the implant site. But the tomographic sections are relatively thick and have adjacent structures that are blurred and superimposed limiting the usefulness of technique especially in anterior region and not useful for determining the bone densities.

Tomography
The word tomography is derived from greek words tomo means slice and graph means picture. It is a body section radiography that enables visualization of section of the patient anatomy by blurring regions of patient anatomy above and below section of interest. Tomographic sections spaced every 1-2mm enables evaluation of implant site region and quantity of alveolar bone available for implant placement.

Computed Tomography
It is a digital and mathematical imaging technique that creates tomographic sections where the tomographic layer is not blurred by structures of adjacent anatomy (Fig: 4) The individual unit is called voxel and has a value referred in Hounse field unit (HU). With current generation CT scanners reformatted images are characterized by a section thickness and in plane resolution of 1pixel (0.25mm) and scan spacing of 0.5mm-1.5mm. This modality offers advantages like density of image is absolute, quantification of alveolar bone, axial view of patient anatomy, uniform magnification with good contrast, easier identification of bone grafts, simultaneous study of multiple implant sites and multi planar views. Unfortunately this technique gives more radiation exposure to patient with limited availability of reconstruction.

Recent advances in Computed Tomography
Cone Beam CT
It uses a conical beam reconstructs the image in any direction using special software. It gives all the information of a Computed Tomography but 1/8 the radiation dose with a lower cost. This technology yields images with isotropic sub millimeter spatial resolution thus it is suited perfectly for oral and maxillofacial region.

Micro Tomography
Another modification of Computed Tomography is especially useful in acquiring serial sections of bone- implant interface.

Interactive Software's
Several different software packages have been
developed to provide an interactive platform which permits the analysis of potential implant sites for bone quantity, quality and morphology assessment. These are SURRLAN for Computed tomography, Denta Scan and Simplant for reformatted Computed tomography. Other software’s like Procera and Vimplant are also available.

**Denta Scan Imaging**

It provides programmed reformed, organization and display of imaging study. Radiologist simply indicates the curvature of the mandibular or maxillary arch and computer is programmed to generate 3D images of the arch. The advantages offered by dentascan are outlined in Line Diagram: 1. Dentascan imaging had limitations like the images were not of true size and require compensation for magnification and determination of bone quality. Dentascan images only include a limited range of diagnostic gray scale of study.

**Simplant**

The program permits the planner to vary the display of reformatted CT images and to inspect the bony anatomy of the alveolar ridge. The advantages include bone height and width can be measured from point to point, the angulations of the proposed implant can be modified and inferior alveolar canal can be easily visualized.

**Interactive Computed Tomography**

This technique enables the radiologist to measure the length and width of alveolus, bone quality by changing the gray levels and provides a three dimensional treatment plan that is integrated within the patient anatomy and can be visualized before implant surgery. Also, it provides Electronic Surgery (ES) by selecting and placing electronic implants at arbitrary positions. The problem frequently encountered with this software is the clinician may struggle in achieving the exact relative spacing and orientation of electronic implants as images obtained are orthogonal rather than three dimensional.

**Determination of Inferior Alveolar Nerve Canal**

It is extremely important to identify the mandibular canal on cross-sectional images and to measure the distance from the top of the alveolar ridge to the top of the canal. Normally, the canal can be readily seen on cross-sectional images of the posterior mandible. What if the canal is hard to visualize on the cross-sectional images? Then two possible solutions are there for assessment of inferior alveolar nerve canal:

i. **Niche Sign**: The mandibular nerve creates an indentation along the inner medullary margin on the lingual cortex of the mandible. As a rule this niche must be seen as a continuous defect on multiple crosssectional images before it can be verified (Fig:7)

ii. **Triangulation**: The method utilizes the scale marker on the films to relate an anatomic structure seen on one view with its location on another view.

**Magnetic Resonance Imaging (MRI)**

Magnetic Resonance Imaging is a quantitatively...
accurate technique which provides exact
tomographic sections without distortion.\(^4\)
Although, it has been proposed as a secondary
imaging technique for dental implants but
provides a major advantage of minimizing
patient risk because of use of non ionizing
radiation.\(^3\) MRI is helpful in determination of
inferior alveolar nerve canal when there is failure
to locate the canal due to osteoporosis or poor
corticated borders.\(^8\) From the stand point of MRI
safety, dental implants are to be considered
similar to other internal orthopedic hardware like
screws, plates, rods and artificial joints.\(^1\)

Radiation Doses from Various Imaging
Modalities Used in Implant Dentistry
When the dentist prescribes a radiographic
e x a m i n a t i o n ,  A L A R A ( A s  L o w  a s
Reasonable Achievable) principle should be
followed. Radiographs should only be
prescribed when the information cannot be
obtained in any less invasive manner.\(^20, 21\)
Computed tomography delivers a relatively
large dose of ionizing radiation. Therefore, it
is important to maximize the diagnostic yield
while simultaneously limiting the field of view to
the region of interest as the number and thickness
of slices influence the total dose to the patient in a
CT examination.\(^7\) Frederiksen and others estimated
that an effective dose of 10 μSv is attained from a
single periapical film exposure; 26 μSv from a
panoramic projection; 150 μSv from a full-mouth
survey; 761 μSv from the CT of the mandible; and
104 μSv from the CT of the maxilla.\(^20, 22\)

Imaging Protocols in Implant Dentistry
Pre prosthetic implant imaging involves the
radiographic examination that assist the implant
team in determining the patient's final and
comprehensive treatment plan. Then intra
operatively, the radiography is required to
confirm the correct placement of implant or to
locate the lost implant. Postoperatively
radiographs assess the status of implant fixature.
The implant site is evaluated for any resorptive
changes, apical migration or indistinct osseous
margins.\(^13\) The various radiographic signs
associated with failing endosseous implants are
outlined in Line diagram 2.
Fig 1: IOPA demonstrating Screw-retained Implants with respect to 11, 21 & 22.

Fig 2: Panoramic radiograph revealing presence of osteoma (arrow) in left maxillary sinus in an asymptomatic patient.

Fig 3: Cropped panoramic radiograph showing ball bearing embedded in acrylic template.
Fig 4: CT scan showing third dimension slices of a 2D image turned 90 degree.

Fig 5 a: Axial CT view of mandible showing the potential cross-sectional slices that can be reformatted by Dentascan

Fig 5 b: Crossectional CT reformatted CT images of same patient as in fig5a. Note the mandibular changes in width and shape in more posterior slices giving distinct appearance of mandibular canals.
Fig 6: Reformatted and enhanced images produced using SimPlant software.

Fig 7: Complex motion cross-sectional tomogram of mandible demonstrating the cortical niche sign (arrows).

To evaluate the available height, width and bone density.

To identify and visualize the proximity to mandibular canal prior to implant placement.

To assess the presence or absence of bony undercuts/bony concavities.

To assess mucosal thickening in maxillary sinus.

No. 1: Advantages offered by Dentascan Imaging
Thin radiolucent area closely follows outline of implant
(Loss of osseo integration)

Saucerized area of bone loss (Adverse loading)

Apical migration of alveolar bone (Improper angulation
leading to non axial loading)

Residual radiolucency in previous normal periapical
area (Incorrect seating of implant)

Peri-implantitis (Rejection / loss of osteo integration)

Fracture of implant fixture (Poor stress distribution
during masticatory function)

No. 2: Radiographic Signs Associated with failing endosseous implants
CONCLUSION
The excellent imaging modalities that exist today can enhance the success and satisfaction of implant placement. Selection of projections should be made with consideration to the type and number of implants, location and surrounding bone anatomy. Thus, diagnostic imaging is an integral part of dental implant therapy.

REFERENCES

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