Dental Implant Imaging : An Overview

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Introduction

Few advances in dentistry have been as remarkable as the use of dental implants to restore orofacial form and function. Dental implants are gaining immense popularity and wide acceptance 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. It is important to be able to place the implants in the mandible and maxilla with a high degree of precision. No tool in dentistry plays a more vital role in diagnosis and treatment planning than radiography.[1]

Dental implantology is now an integral part of conventional dental practice hence every dentist should be familiar with the radiographic appearance of the various implant fixtures and also know about current implant imaging techniques. The reliability of the current implant systems derive, in part, from the increasingly sophisticated imaging techniques used in all phases of implant treatment. The intent of this review is to provide an overview on the role of diagnostic imaging in pre, intra and postoperative evaluation of the dental implant patient.

Imaging objectives

The decision of when to image along with which imaging modality to use depends on the three phases.[2]

1. **Preprosthetic implant imaging (Phase 1):** The objectives of this phase are to deter-mine the quantity, quality, and angulation of bone; the relationship of critical structures to the prospective implant sites; and the presence or absence of disease at the proposed surgery sites.
2. **Surgical and Interventional implant imaging (Phase 2):** The objectives of this phase are to evaluate the surgery sites during and immediately after surgery, assist in the 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.
3. **Post prosthetic implant imaging (Phase 3):** It commences just after the prosthesis placement and continues as long as implant remains in the jaws. The objectives of this phase are 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.

Ideal imaging Modality Characteristics According to Pharoah MJ 1993

1. The type of imaging technique selected should be able to provide the required information with adequate precision and dimensional accuracy.
2. Cross-sectional views for the visualization of the spatial relationship of internal structures, such as the inferior alveolar canal, and as a means of obtaining accurate dimensions in both the vertical and the horizontal planes.
3. Minimal image distortion to permit accurate measurements.
4. Depiction of the density of the cancellous bone and thickness of the cortical plates of bone. This is of value if initial stabilization of the implant is required.
5. Spatial relationship of the cross-sectional views of the mandible and maxillae to one another.
6. A simple means of identifying the exact location of each cross-sectional image to the implant site that can be provided at the time of surgical placement.
7. Ready availability and reasonable cost.
8. Imaging information should be balanced with the radiation dose and cost to the patient. The ALARA (as low as reasonably achievable) principle should govern the selection of suitable technique.[3]

Imaging Modalities

The commonly used radiographic procedures with time intervals for treatment planning and assessment of dental implants are as shown in the **Table :**

Stage of treatment	Time(mo)	Radiographic procedure
Treatment planning	-1	PA, pan, tomo, CBCT/ MDCT, ceph
Surgery (placement)	0	PA, pan, tomo, CBCT/MDCT,ceph
Healing	0-3	PA, pan, tomo, CBCT/MDCT,ceph
Remodelling	4-12	PA, pan
Maintenance (without problem)	13+	PA, pan (following approximately every 3 years)
Complications	Anytime	PA, pan, tomo, CBCT/MDCT

PA, Periapical; pan, panoramic, tomo, conventional tomography; CBCT, cone-beam tomography; MDCT, multidetector computed tomography; ceph, lateral /lateral oblique cephalometric radiography.

Intra Oral Periapical Radiography

IOPA radiographs are commonly used to evaluate the status of adjoining teeth and remaining alveolar bone in mesio-distal dimension. They may also be used for determining vertical height, architecture, and bone quality.[3,4]

Advantages

- Readily available
- High image definition
- Minimal distortion
- Least cost and radiation exposure

Disadvantages

- Limited imaging area
- No facial- lingual dimension
- Limited reproducibility
- Image elongation and foreshortening

Intraoral Occlusal Radiography

Occlusal radiographs are sometimes used to determine facio-lingual dimensions of the mandibular alveolar ridge whereas it is not useful in imaging maxillary arch due to anatomic limitations.[5]

Advantages

- Readily available
- High image definition
- Gross facial-lingual dimension
- Relatively large imaging area
- Least cost and radiation exposure

Disadvantages

- No detailed facial- lingual dimension
- Limited reproducibility
- Not as applicable for maxilla

Panoramic Radiography

Panoramic radiographs are useful in making preliminary estimation of crestal bone, cortical boundaries of the mandibular canal, maxillary sinus, and nasal fossa. Information acquired from a panoramic should be judiciously used because of image size distortion. Angular measurements on panoramic radiographs tend to be accurate, but linear measurements are not.

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. These devices employ limited angle linear tomography (zonography) and a means for positioning the patient. This technique enables the appreciation of spatial relationship between the critical structures

and implant site and quantification of geometry of implant site. It has limited usefulness, especially in the anterior regions. The tomographic layers are relatively thick and have adjacent structures that are blurred and superimposed on the image, limiting the usefulness of this technique for individual sites, especially in the anterior regions where the geometry of alveolous changes relatively rapidly. This technique is not useful for determining the differences in most bone densities or identifying disease at implant site.[2,6]

Advantages
- Readily available
- Relatively large imaging area
- Least cost and radiation exposure

Disadvantages
- No detailed facial- lingual dimension
- Image distortion
- Inconsistent magnification and geometric distortion

Lateral Cephalometric Radiography

Lateral cephalograms provide an image of known magnification (usually 7%-12%) that document axial tooth inclinations and the dento-alveolar ridge relationships in the midline of the jaws. This projection can provide a cross-sectional view of only the maxillary and mandibular midline. [3]

Advantages
- Readily available
- Useful in placement of implants near the midline
- Least cost and radiation exposure

Disadvantages
- No detailed facial- lingual dimension
- Inconsistent magnification and geometric distortion

Conventional Tomography

Used as an adjunct to screening films, cross-sectional tomograms enhance visualization of the available bone by providing reliable dimensional measurements at proposed implant sites, including the cross-sectional (facial-lingual) dimension. To obtain reliable measurements, it is imperative that the image layer be a true cross-section of the curve of the alveolar process, rather than oblique. Scout films (usually submento-vertex, occlusal or panoramic) or wax bite registration or dental models commonly are used to determine appropriate cross-sectional angulations.[1,2,6]

Advantages
- Minimal superimposition
- Facial-lingual dimension
- Uniform magnification
- Measurements accurate within about 1 mm
- Moderate cost
- Simulates placement with software

Disadvantages
- Less image definition than plain films
- Somewhat limited availability
- Special training for interpretation
- Sensitive to technique errors
- Greater radiation exposure for multiple sites

Reformatted Computed Tomography

Patients who are edentulous or who are being considered for multiple implants and augmentation procedures may be best imaged with CT in order to investigate all possible implant sites. The CT analysis results in three basic image types: axial images with a superimposed curve, reformatted cross-sectional images made perpendicular to the cure, and panoramic-like images reconstructions are made parallel with the curve. Three dimensional representations may also be constructed in various orientations. These reformatted images provide the clinician with two-dimensional diagnostic information in all three dimensions.[2,3,7]

Cone Beam Computed Tomography

Cone beam CT is a relatively newer modality, specifically designed for maxillofacial imaging introduced in the late 1990s. It is characterized by true volumetric data acquisition obtained simultaneously during one rotation of the x-ray source. It produces a 3-D image volume that can be reformatted using software for customized visualization of the anatomy. It gives all the information of CT at 1/8th the radiation dose and at a lower cost.[8]

Tuned Aperture Computed Tomography (TACT)

TACT is a new and promising method for dentoalveolar imaging based on optical aperture theory. This technique uses information collected by passing a radiograph beam through an object from several different angles. A prototype developed for dental applications has a cluster of small radiograph tubes that can be fired in close sequence. The relationship of the source and the object can be used to determine projection geometry after the exposure is complete. TACT can map the incrementally collected data into a single 3-dimensional matrix. It can isolate the images of desired structures limited to certain depths. It has the ability to accommodate patient's motion between exposures. It has considerable flexibility to adjust contrast and resolution.[9]

Advantages
- Allows evaluation of all possible sites
- No superimposition
- Uniform magnification
- Measurements accurate within about 1 mm
- Estimates internal bone density
- Simulates placement with software

Disadvantages
- Limited availability
- Sensitive to technique errors
- Metallic image artifacts
- Special training for interpretation
- High cost and radiation exposure
- Volume averaging contributes to measurement errors

Magnetic resonance imaging (MRI)

Magnetic resonance imaging (MRI) is based on the phenomenon of nuclear magnetic resonance (NMRI). First described in 1946, its application in implantology is however of recent origin.[10] MRI with a 0.2 Tesla low field scanner, has shown definite potential as a future replacement for CT imaging with the obvious advantages that it delivers no ionizing radiation.[11] MRI is used in implant imaging as a secondary imaging technique when primary imaging techniques fail. MRI visualizes the fat in trabecular bone and differentiates the inferior alveolar canal and neurovascular bundle from the adjacent trabecular bone.[12] Oriented MRI imaging of the posterior mandible is dimensionally quantitative and enables spatial differentiation between critical structures and the proposed implant site. MRI is not useful in characterizing bone mineralization or a high-yield technique for identifying bone or dental disease.[13]

Advantages
- MRI can sharply delineate soft and hard tissues
- Differentiate between cortical and cancellous bones,
- Zero radiation dose,
- Flexibility of plane acquisition,
- Gives good soft tissue details and fewer artifacts.

Disadvantages
- Expensive
- No special software is available for specific use in implantology
- An expert radiologist is required to interpret
- Its application in implantology is still in its experimental phase .

The role of diagnostic imaging in preoperative planning

Radiographic visualisation of potential implant sites is an important extension of clinical examination and assessment.[14] Radiographs help by providing relevant information on:
- Alveolar ridges and supporting structures in all three dimensions and guide the choice of site, number, size and axial orientation of the implants.
- The position and size of relevant normal anatomical structures, including the inferior dental canals, mental formina, incisive foramen and canal, nasal floor and the maxillary sinus.
- The presence of underlying osseous pathoses, retained roots or buried teeth.

Quality of Bone
- Assessment of the cortical bone because it is best suited to withstand the functional loading forces of dental implants.
- A greater number of internal trabeculae per unit area are also advantageous.[3,15]

Quantity of Bone
- It is assessed by documenting the height and width of available alveolar bone and morphology of the ridge.
- A cross-sectional image helps to document the facial-lingual width and height of the ridge, along with the inclination of the bone contours.
- Morphologic features such as osseous undercuts and ridge concavities that are not immediately apparent on clinical examination become evident with imaging.
- The clinical utility of presurgical imaging can be enhanced by the use of an imaging stent that helps relate the radiographic image and its information to a precise anatomic site.
- Diagnostic interactive software are available for both conventional and reformatted computed tomography and provide an interactive analysis of potential implant sites for bone quantity,

quality and morphology and can simulate surgical placement of the implant.[3,16]

The role of diagnostic imaging in intraoperative and postoperative planning

Intraoperative imaging may be required to confirm the correct placement of the implant or to locate the lost implant.[6,17] The objectives of this post operative phase are 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**.** The two aspects that are usually assessed with time after implant placement are the alveolar bone height around the implant and the appearance of the bone immediately adjacent to and surrounding the implant.

Criteria for Success

Ideally, implants should be evaluated against standardized success criteria and not simply assessed for their survival. Albrektsson in 1986 put forward the following criteria for success:

- That an individual, unattached implant is immobile when tested clinically.
- That a radiograph does not demonstrate any evidence of peri-implant radiolucency.
- That vertical bone loss be less than 0.2 mm annually following the implant's first year of service.
- That individual implant performance be charachterized by an absence of signs and symptoms such as pain, infection, neuropathies , paraesthesia or violation of an anatomic structure
- That, in the context of the above, a success rate of 85% at the end of a 5- year observation period and 80% at the end of a 10 year period be the minimum criteria for success.[6]

Radiographic Evaluation

Radiographs allow evaluation of criteria 2 and 3, but also are used to assess:

- The position of the fixture in the bone and its relation to nearby anatomical structures.
- Healing and integration of the fixtures in the bone.
- The peri-implant bone level and any subsequent vertical bone loss- threaded fixtures allow easy measurement if radiographs are geometrically accurate
- Development of any associated disease eg. perimplantitis
- The fit of the abutment to the fixture
- The fit of the abutment to the crown/ prosthesis
- Possible fracture of the implant/ prosthesis.

Radiographic Signs Associated with Failing Endosseous Implants

Radiographic Appearance	Clinical implication
Thin radiolucent area that closely follows the entire outline of the implant	Failure of the implant to integrate with the adjoining bone.
Crestal bone loss around the coronal portion of the implant	Osteitis resulting from poor plaque control, adverse loading , or both
Apical migration of alveolar bone on one side of implant	Nonaxial loading resulting from improper angulation of the implant
Widening of the periodontal ligament space of the nearest natural(tooth) abutment	Poor stress distribution resulting from biomechanically inadequate prosthesis-implant system
Fracture of the implant fixture	Unfavourable stress distribution during function

Selecting the Right Imaging Technique

The choice of imaging technique is based on radiation dose, cost and availability of an oral and maxillofacial radiologist to interpret the images. The American Academy of Oral and Maxillofacial Radiology (AAOMR)[18] has described the selection criteria for dental implant imaging. To assess the suitability of an implant site, the clinician must be able to visualize the mesialdistal view of the region of the arch where implant placement is being considered. In general, the appropriate image for this purpose is a panoramic radiograph. Periapical views may be added in cases where more detailed images are required. If the panoramic radiograph shows that there is sufficient bone for implant placement in that dimension, the practitioner should then identify the potential implant sites and obtain cross-sectional images to evaluate the adequacy of bone in the buccolingual dimension. Panoramic radiographs are generally useful to rule out gross pathoses within the jaws.[19] Cross-sectional information can be acquired with either conventional tomography or CT,[17] with images recorded on film or digitally acquired. Generally, if images are required of all the maxilla and mandible to evaluate possible implant sites, then computed tomography would be best modality. If potential sites are restricted to a few selected regions, then conventional tomography would be a suitable choice. However, the ease of acquisition and relatively low radiation risk of CBCT makes this technique a very viable alternative study even for single implants.

Although routine use of radiographs to assess the status of implant fixtures is not necessary, only when the clinical evidence indicates the need imaging modalities may be used to evaluate the implants postoperatively. Before the restorative phase, the implant is checked clinically for indications of successful osseointegration. Imaging modalities used in postoperative evaluation of the dental implant patient include panoramic radiography, direct axial CT, and reformatted panoramic, cross-sectional, and 3D imaging. Panoramic radiography is undoubtedly the most widely used imaging modality in postoperative evaluation of the dental implant patient; panoramic radiographs are used routinely to assess bone healing around the fixture. Axial CT and reformatted panoramic, crosssectional, and 3D images can be of great value when one is concerned about possible complications associated with placement of an intraosseous fixture. Although the fixture is composed of a metal, usually titanium or an iitanium alloy, it is not a major problem in performing CT on dental implants.

Axial CT sections are useful in evaluating osseointegration by demonstrating the presence or absence of bone-to-metal contact, as well as complications associated with implant failure. Cross-sectional reformatted images are useful in assessing osseointegration, while 3D and reformatted panoramic and cross-sectional images are useful in assessing proper placement of a fixture. A major complication of incorrect implant placement is violation of an adjacent structure (eg, the nasal fossa, maxillary sinus, or mandibular canal). This complication can be evaluated with reformatted cross-sectional or panoramic images or 3D images of the structure involved.[20]

Conclusion

Dental implantology is a rapidly expanding area of dentistry. The excellent imaging modalities that exist today can enhance the success of and satisfaction with implant placement. Selection of projections should be made with consideration of the type and number of implants, location and surrounding anatomy. As in the case of all imaging, appropriate selection criteria must be applied individually to each patient. The information presented in this review should provide the radiologist with an overview of the role of imaging and its best use in the field of dental implants.

References

For a complete list of references are available on request, Please mail us editor @healtalkht.com