Implant Imaging: A Review of Literature

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Dental implants have revolutionized the field of dentistry and have gained immense popularity in recent days. It has become the choice of replacement of missing tooth in present days. It replaces the missing tooth without interference with oral function and speech. For perfect outcome of implant treatment, pre-surgical planning is important in which imaging plays a major role where two-dimensional and three-dimensional views guide the dentist in perfect placement of an implant. Imaging of implant site is also used in surgical and post-surgical phases to determine success and failure of implants. This article mainly reviews different imaging modalities and their clinical implications used for implants.

Keywords: Cone beam computed tomography, Dentascan, Electronic surgery, Implant imaging, Interactive computed tomography

INTRODUCTION

Implants have become successful and widespread choice of replacement and rehabilitation of missing teeth either partially or completely edentulous over past 30 years.¹,² Many changes have took place in diagnosis and treatment planning of implants which is improving success rate of implants. It is important to know the jaw size, boundaries, orientation of jaws, and height and width of bone to decide type and number of implants in which Radiographic examination plays a major role.³

ROLE OF IMAGING IN IMPLANT TREATMENT

Implant treatment planning mainly involves patient history, clinical examination, and radiographic examination.⁴ A thorough radiographic examination is necessary for planning implant treatment. It helps in diagnosing type and number of implants to be placed, bone quantity and quality and vital anatomic structures to be taken into consideration.⁴

Pre-operative treatment planning involves a radiographic examination which helps in following ways:
1. In identification of pathologic conditions associated with teeth, jaws, or bone
2. In assessment of bone quality and quantity of implant site
3. In identification of vital structures such as proximity of nasal fossae, neurovascular bundles, pneumatization of maxilla, soft tissue morphology.⁵,⁶

CRITERIA FOR SELECTING RADIOGRAPHIC METHOD

The following methods of radiography help in guiding the technician selecting an appropriate imaging method:
1. Adequate number of images should be available to provide required information
2. It should provide required information with adequate precision and dimensional accuracy
3. There must be a way of relating images to patient anatomy
4. It should have adequate density and contrast with no artifacts
5. Information should be balanced with radiation dose and cost to the patient and satisfy risk/benefit ratio and also ALARA principle should govern the selection of radiographic method.⁶

IMAGING MODALITIES

Currently, many imaging modalities are available which helps in deciding implant treatment.

They can be classified depending on phase of treatment as:
1. Pre-prosthetic phase:
Table 1: Uses, advantages, disadvantages of two-dimensional radiography methods

<table>
<thead>
<tr>
<th>Imaging modality</th>
<th>Uses</th>
<th>Advantages</th>
<th>Disadvantages</th>
</tr>
</thead>
<tbody>
<tr>
<td>Periapical radiography</td>
<td>1. To rule out dental or bone disease identifying vital structures</td>
<td>1. Readily available</td>
<td>1. Limited imaging area</td>
</tr>
<tr>
<td>Digital radiography</td>
<td>1. Image modifications i.e., contrast and brightness adjustments can be done easily</td>
<td>1. Low radiation exposure to patient</td>
<td>4. Image distortion</td>
</tr>
<tr>
<td></td>
<td>2. The image can be viewed in all angles</td>
<td>2. Increased patient comfort</td>
<td>5. Bone quantity cannot be determined</td>
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<tr>
<td></td>
<td>3. Measurements can be taken</td>
<td>3. Cost effective</td>
<td></td>
</tr>
<tr>
<td></td>
<td>4. Single or multiple images can be printed easily</td>
<td>4. Instant results are obtained</td>
<td></td>
</tr>
<tr>
<td>Occlusal radiography</td>
<td>1. Helps in determination of jaw size, curvature of jaw at implant site</td>
<td>1. Provides generalized information about bone density</td>
<td>1. Medio lateral extension of bone is not seen</td>
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<tr>
<td></td>
<td>2. Determining the geometry or the degree of mineralization of the implant site</td>
<td>2. Readily acceptable</td>
<td>2. Image distortion due to lingual inclination</td>
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<tr>
<td></td>
<td>3. Critical structures such as the maxillary sinus, nasal cavity, and nasal palatine canal are demonstrated</td>
<td>3. Cost effective</td>
<td>3. It shows the widest width of bone (i.e., the symphysis) versus the width at the crest, which is where diagnostic information is needed most</td>
</tr>
<tr>
<td>Cephalometric radiography</td>
<td>1. It helps in demonstration of geometry of alveolus in anterior region and relationship of lingual plate to patient skeletal anatomy</td>
<td>1. Soft tissue profile can be detected to evaluate profile alterations after prosthetic rehabilitation</td>
<td>1. Quality of bone cannot be determined</td>
</tr>
<tr>
<td></td>
<td>2. Width of bone in symphyseal region and relation between buccal cortex and roots of anterior teeth may also be determined</td>
<td>2. Spatial relationship between implant site and critical structures can be detected</td>
<td>2. Limited use in anterior region</td>
</tr>
<tr>
<td></td>
<td>3. It evaluates loss of vertical dimension, skeletal arch inter relationship, anterior tooth positioning in prosthesis and resultant movement of forces</td>
<td>3. Image magnification is constant</td>
<td>3. Superimposition of structures</td>
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<tr>
<td></td>
<td></td>
<td>4. Low radiation dose</td>
<td>4. Reveals only maximum buccal-lingual width and not depression in ridge</td>
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<td></td>
<td>5. Cost effective</td>
<td></td>
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<tr>
<td>Panoramic radiography</td>
<td>1. It helps in identification of anatomical spatial relationship opposing landmarks can be easily identified</td>
<td>1. It acts as excellent screening tool for pre-surgical treatment planning</td>
<td>1. It demonstrates vertical magnification of 10% and horizontal magnification of 20% and distortion caused due to magnification cannot be compensated in treatment planning</td>
</tr>
<tr>
<td></td>
<td>2. It helps in identification of vital structures adjacent to implant site</td>
<td>2. The procedure can be performed with ease, convenience and speed</td>
<td>2. Artifacts limit diagnostic accuracy</td>
</tr>
<tr>
<td></td>
<td>3. Vertical height/quantity of bone can be identified</td>
<td>3. Low cost to the patient with minimal radiation dose</td>
<td>3. Quality of bone cannot be determined</td>
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<td>4. Little or no information about width or ridge inclination</td>
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<td>5. Sharpness and image resolution is less</td>
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</tbody>
</table>

CT: Computed tomography

Table 2: Uses, advantages, disadvantages of three-dimensional radiography methods

<table>
<thead>
<tr>
<th>Imaging method</th>
<th>Uses</th>
<th>Advantages</th>
<th>Limitations</th>
</tr>
</thead>
<tbody>
<tr>
<td>Conventional tomography</td>
<td>1. Determination of specific implant site can be done</td>
<td>1. Accurate than periapical and panoramic radiography</td>
<td>1. It is not useful in determining bone quality</td>
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<tr>
<td></td>
<td>2. It helps in assessment of bone height, width, inclination of ridge and anatomic spatial relationship</td>
<td>2. Cost is less than CT</td>
<td>2. Image blurring and magnification is seen</td>
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<td></td>
<td>3. Digitalization of images helps in which aid in determining alveolar bone by using digital ruler, and in identifying critical structures</td>
<td>3. Detioration of section due to scatter artifact on CT is not seen in conventional radiation</td>
<td>3. Misinterpretation of actual angulation result in improper placement or angulation of implant</td>
</tr>
<tr>
<td>CT</td>
<td>1. Helps in patient education and motivation</td>
<td>4. Exposure is less than computed tomography</td>
<td>4. Not easily available</td>
</tr>
<tr>
<td></td>
<td>2. Position of critical structures can be accurately determined</td>
<td></td>
<td>5. Transfer of information to clinical site may necessitate imaging stent</td>
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<tr>
<td></td>
<td>3. Use of CT scan splint lined with barium sulfate in tooth portion template helps in evaluation of proposed tooth position, abutment selection and implant placement</td>
<td>4. Allows evaluation of all possible sites</td>
<td>1. Limited availability</td>
</tr>
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<td></td>
<td></td>
<td>2. No superimposition</td>
<td>2. Sensitive to technique errors</td>
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<td></td>
<td>3. Uniform magnification</td>
<td>3. Metallic image artifacts</td>
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<td>4. Accurate measurements simulates placement with software</td>
<td>4. Special training for interpretation</td>
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<tr>
<td></td>
<td></td>
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<td>5. High cost</td>
</tr>
</tbody>
</table>

CT: Computed tomography

- Periapical radiographs
- Occlusal radiographs
- Orthopantomography
- Cephalometric radiography
- Computed tomography (CT)
- Magnetic resonance index (MRI)
2. Surgical/interventional phase:
   • Periapical radiographs
   • Orthopantamographs.

3. Post-surgical phase:
   • Periapical radiographs
   • Orthopantamographs.

They can also be classified as:
1. Two-dimensional analog/digital:
   • Periapical radiographs
   • Occlusal radiographs
   • Orthopantomographs
   • Cephalometric radiographs.

2. Three-dimensional:
   • Conventional tomography
   • CT
   • Cone beam CT
   • MRI.

### Bone Classification Related To Implant Dentistry

1. Lekholm and Zarb\textsuperscript{7} alveolar bone grading scale.

According to this system alveolar bone has been divided into 4 classes:
- Almost the entire jaw bone is composed of homogeneous compact bone
- Thick layer of compact bone surrounds a core of dense trabecular bone
- A thin layer of compact bone surrounds a core of dense trabecular bone of favorable strength
- A thin layer of compact bone surrounds a core of low density trabecular bone.

The quality of the implant site in terms of relative proportion and density of cortical and medullary bone had frequently been assessed using a grading scheme.

2. Lindh \textit{et al.}\textsuperscript{8} method of classification of alveolar bone.

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**Table 3: Radiographic changes which indicate implant failure are listed\textsuperscript{10,13}**

<table>
<thead>
<tr>
<th>Radiographic appearance</th>
<th>Clinical implications</th>
</tr>
</thead>
<tbody>
<tr>
<td>Thin radiolucent line that closely follows outline of implant (Figure 11)</td>
<td>Failure of implant osseointegration with adjacent bone</td>
</tr>
<tr>
<td>Crestal bone loss around coronal portion of implant</td>
<td>Adverse loading or osteitis resulting from poor plaque control</td>
</tr>
<tr>
<td>Apical migration of alveolar bone on one side of implant</td>
<td>Non-axial loading resulting from improper angulation of implant</td>
</tr>
<tr>
<td>Widening of periodontal ligament space of nearest natural abutment</td>
<td>Poor stress distribution resulting from inadequate biomechanical prosthesis implant system</td>
</tr>
<tr>
<td>Fracture of implant fixture (Figure 12)</td>
<td>Unfavorable stress distribution during function</td>
</tr>
<tr>
<td>Rapid bone loss (Figures 13)</td>
<td>Fractured fixture, initial osseous trauma at insertion, occlusal trauma, poor adaptation of prosthesis to abutment</td>
</tr>
</tbody>
</table>

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2. Figure 1: Identification of vital structures and quality of bone with periapical radiographs

3. Figure 2: Identification of vital structures and quality of bone with periapical radiographs

4. Figure 3: Digital imaging seen on computer screen

It is a recent method of classification based on periapical radiographs that grades the medullary bone as:
- Dense
- Sparse
- Alternating dense and sparse trabeculation.
3. Misch Bone Density Classification
   - D1: Dense cortical bone
   - D2: Thick dense to porous cortical bone on crest and coarse trabecular bone within
   - D3: Thin porous cortical bone on crest and fine trabecular bone within,
   - D4: Fine trabecular bone and
   - D5: Immature, non-mineralized bone.

Uses, advantages and disadvantages of various two dimensional and three dimensional methods age given in (Table 1 & 2) When using intra oral periapical radiography the error commonly observed is distortion due to incorrect horizontal or vertical angulation this can be eliminated using paralleling technique with high speed films. The most common radiograph used in diagnosis of implant treatment is panoramic imaging the most common error seen is magnification, and it can be corrected by placing ball bearings of known dimension in edentulous area before taking radiograph by which magnification can be calculated. A modification of the panoramic X-ray machine called zonography has been developed which is capable of making cross-sectional images of jaws. This technique helps in identification of spatial relationship between the critical structures and the implant site. The tomographic layers are 5 mm thick approximately and the adjacent structures are blurred and superimposed on the image, limiting the usage of this technique to individual sites, especially in the anterior regions where there is rapid change of geometry of the alveolus. This technique is not useful for determining the differences in most bone densities or identifying disease at the implant site.1,5

**RECENT ADVANCES IN CT**

**Cone Beam CT**
It is an innovative technology in radiology that is characterized by acquisition of volumetric data with conical beam which helps in customized visualization with reformatted softwares. It gives all the information of a CT with improved resolution of the image but, at the radiation dose which is 1/8th of CT and at a lower cost.1,10,11
Microtomograph
It is also modification of CT which is useful in acquiring serial sections of bone-implant interface.\textsuperscript{12}

Dentascan Imaging: (Figure 9)
It is a CT software which images maxilla and mandible in three views, i.e., axial, panoramic, and cross-sectional. It helps in evaluation of bone morphology and osseous structures of maxilla and mandible. When the radiologist indicates curvature of the mandibular or maxillary arch, alveolus along with three-dimensional images of the arch which are spaced 1 mm apart are generated by computer which enables accurate pre-prosthetic treatment planning.

Limitations include:
1. True size images are not produced and require correction of magnification and
2. Bone quality cannot be determined.

To take full advantage of the technique, a diagnostic template is necessary which delivers three-dimensional treatment plan of the final prosthetic result into the imaging examination to evaluate the patient’s anatomy relative to the proposed implant sites.\textsuperscript{1,5}

Interactive CT (ICT) (Figure 10)
It is one of the most recent and innovative technology which bridges the gap in information between the radiologist and the practitioner. It is a computer aided program which transfers the imaging study to the clinician as a computer file where the clinician can view, interact and serves as diagnostic radiologic workstation to determine length and width of the alveolus, bone quality, and the level of the gray scale to enhance the perception of critical structures. An important feature of ICT is that an “electronic surgery” (ES) can be performed by clinician by selecting and placing arbitrary size cylinders simulating root form implants which helps in patient’s treatment plan in three-dimensions. Hence, ES and ICT empowers the development of a three-dimensional treatment plan which is integrated with the patient’s anatomy and visualized before implant surgery by the members of the implant team and the patient for approval or modification. The number and size of implants along with the density of bone at the proposed implant sites can be accurately determined before surgery. Currently,
ICT is the most accurate imaging technique for implant treatment planning but limitations include refinement and exact relative orientation of the implant positions in spite of enabling placement of electronic implants in the imaging study. It is also difficult for clinician to achieve exact spacing, orientation and parallelism. A diagnostic template can be converted into a surgical template, which is a computer generated three-dimensional stereotactic surgical template, obtained from the digital ICT an ES data.\textsuperscript{1,5,11}

**IMPLANT IMAGING IN DIFFERENT PHASES**

**Pre-prosthetic Implant Imaging**

In post prosthetic imaging add some of failures of implants detected radiographically are given in Table 3. This phase is intended to evaluate the current status of the patient’s teeth and jaws and required surgical and prosthetic information and to develop and refine the patient’s treatment plan. The specific objectives of pre-prosthetic imaging are to:

1. Identify disease
2. Determine bone quantity and bone density,
3. Identification of critical structures such as mental foramen, inferior alveolar nerve at the proposed implant regions.
4. Determine the optimum position of placement of implant relative to occlusal loads.

Different two-dimensional and three-dimensional views are required in this phase, but three-dimensional views in addition to primary examination is used which identifies amount of bone width, the ideal position and orientation of each implant, its optimal length and diameter, the presence and amount of cortical bone on the crest, the degree of mineralization of bone, and the position or relationship of critical structures at each prospective implant site the to the proposed implant sites.\textsuperscript{5,10}

**SURGICAL AND INTERVENTIONAL IMAGING**

Surgical and interventional imaging involves imaging the patient during and immediately after the surgery and during prosthetic placement. The purpose of this phase includes:

1. Evaluating depth of implant placement
2. Assisting in optimal position and orientation of implant
3. To evaluate any impairment in proper seating of abutment
4. To evaluate whether margins are acceptable around margins and teeth.

Modalities which are mainly used in this phase are digital periapical imaging which gives instant and accurate results and sometimes panoramic radiographs are used when multiple implants are placed.\textsuperscript{5,10,11}

**POST-PROSTHETIC IMPLANT IMAGING**

This phase starts after placement of prosthesis and continues until implants remain in jaws. Objectives of this phase are:

1. Evaluating long-term maintenance of implant rigid fixation and function
2. Evaluating crestal bone level around each implant
3. Excessive functional loading
4. Regular evaluation of changes in mineralization in the implant site which include successful integration, fibrous tissue artifacts, inflammation, infection, and loss of crestal bone adjacent to dental implant.

The successful healing of dental implants result in osseointegration which is defined as contact between implant and bone at light microscopic level. Since histological examination is not possible radiography stands as alternative method to assess fate of dental implant.\textsuperscript{10,11}
CONCLUSION

The implantologist should have clear idea about choosing correct radiographic procedure for correct treatment planning which helps in successful outcome of implant treatment. It also enhances success and satisfaction of patient at the same time satisfying cost benefit ratio to the patient.

REFERENCES