Journey from 2D to 3D: Implant imaging a review

Anil Kumar N.1, Gaurav Agrawal2, Anchala Agrawal1, Sreedevi1, Ankur Kakkad1

1Department of Oral Medicine and Radiology, Hitkarini Dental College and Hospital, Jabalpur, Madhya Pradesh, India; 2Department of Oral Pathology, SMBT Dental College and Hospital, Sangamner, Maharashtra, India

Abstract

Imaging techniques play an important role in proper treatment planning for dental implant. Conventional radiographic imaging techniques provide sufficient information regarding suggested implant sites. But, small size, image distortion, and magnification limit their use in many cases. Previously computed tomography (CT) has been employed for pre-operative planning of implant. The major disadvantages of CT are artifacts, high dose of radiation, and cost. Advanced imaging modalities like cone-beam CT produces three-dimensional images at relatively low cost and radiation dose thus making it invaluable in coordination with other techniques providing the anatomical information thus helps in proper treatment plan, good prognosis and thus relatively low risks for surgical mishaps.

Keywords: Artifacts, dental implants, imaging modalities, radiation risk

Introduction

The use of dental implants in oral rehabilitation has become an integral part of treatment for restoring edentulous spaces. The purpose of tooth replacement with implants is to restore adequate function and esthetics without affecting adjacent hard and/or soft tissue structures. Diagnostic radiography is essential for implants in pre-operative, intraoperative, and post-operative assessment by use of a variety of imaging techniques. In the past, periapical radiographs, occlusal radiograph along with panoramic images were used as the sole determinants of implant diagnosis and treatment planning; as these radiographic modalities provide a two-dimensional (2D) representation of three-dimensional (3D) structures. Hence, the advancement of radiographic technology including, cephalometrics, computed tomography (CT), magnetic resonance imaging (MRI) as well as cone-beam CT (CBCT) is increasingly considered essential for optimal implant placement. 3D information is essential for the implantologist before placement of osseointegrated dental implants. The fundamental basis for radiological examination is to maximize the ratio of the benefit/risk, as imaging for the planning of implant placement is confusing because of the large number of modalities available. Clinicians, however, must recognize that each technique has advantages and limitations. It is essential to consider treatment objectives and patient needs carefully before performing or ordering imaging tests.

The objectives of diagnostic imaging depend on:

1. Amount and type of information required (i.e., combinations of conventional dental images)
2. Least radiation risk to the patient; and
3. Appropriate clinical examination and patient’s need.

The ideal imaging technique for dental implant care should have several essential characteristics including:

1. The ability to visualize the implant site in the mesiodistal, buccolingual, and superoinferior dimensions
2. The ability to allow reliable, accurate measurements
3. Normal anatomical structures (incisive canal, nasal floor, maxillary sinus, mandibular canal)
4. Capacity to evaluate trabecular bone density and cortical thickness (height, width)
5. Reasonable access
6. Cost-effective and
7. Minimal radiation risk (as low as reasonably achievable) [Tables 1 and 2].

**Periapical radiography**

Long cone paralleling technique is the technique of choice for taking periapical radiographs. Among all the imaging modalities, intraoral periapical radiographs offer the best resolution (line pairs/mm), area of interest can be examined for trabecular patterns, residual roots, periodontium, as well as angulation of adjacent teeth, readily available, inexpensive, less radiation dose.

**Limitations**

2D perspective of 3D anatomy, thus not adequate to estimate the amount of available bone (facio-lingual dimension) in the edentulous site, their limited size makes them inadequate for evaluating large edentulous areas and associated maxillary and mandibular structures, distortion of obtained image, anatomic limitations, and image receptor flexibility [Figure 1a-c].

**Digital intraoral radiographic images**

Advantage of this over conventional periapical radiography is 75-90% less exposure, instant results, contrast can be manipulated.

**Table 1:** Commonly used radiographic procedures with time intervals for treatment planning and assessment of dental implants

<table>
<thead>
<tr>
<th>Stage of treatment</th>
<th>Time (months)</th>
<th>Radiographic procedures</th>
</tr>
</thead>
<tbody>
<tr>
<td>Treatment planning</td>
<td>−1</td>
<td>PA, Pan, Tomo, CT, Ceph</td>
</tr>
<tr>
<td>Surgery (placement)</td>
<td>0</td>
<td>PA, Pan, Tomo, CT, Ceph for correction of problems</td>
</tr>
<tr>
<td>Healing</td>
<td>0–3</td>
<td>PA, Pan, Tomo, CT, Ceph for correction of problems</td>
</tr>
<tr>
<td>Remodeling</td>
<td>4–12</td>
<td>PA, Pan</td>
</tr>
<tr>
<td>Maintenance (without problems)</td>
<td>13+</td>
<td>PA, Pan, (follow-up approximately every 3 years)</td>
</tr>
<tr>
<td>Complications</td>
<td>Anytime</td>
<td>PA, Pan, CT (as indicated)</td>
</tr>
</tbody>
</table>

PA: Periapical, Pan: Panoramic radiography, Tomo: Conventional tomography, CT: Reformatted computed tomography

**Table 2:** Imaging modalities and limitations

<table>
<thead>
<tr>
<th>Analog/two dimensional</th>
<th>Digital/three dimensional</th>
</tr>
</thead>
<tbody>
<tr>
<td>Periapical</td>
<td>Computed tomography (CT)</td>
</tr>
<tr>
<td>Digital periapical</td>
<td>DentaScan imaging</td>
</tr>
<tr>
<td>Bitewing</td>
<td>ICT</td>
</tr>
<tr>
<td>Occlusal</td>
<td>MRI</td>
</tr>
<tr>
<td>Panoramic</td>
<td>CBCT, MDCT</td>
</tr>
<tr>
<td>Lateral cephalometric</td>
<td></td>
</tr>
</tbody>
</table>

CT: Computed tomography, ICT: Interactive computed tomography, MRI: Magnetic resonance imaging, CBCT: Cone-beam CT, MDCT: Multi-detector CT

**Figure 1:** (a-c) Periapical radiograph showing implant fixtures, along with abutment
in inferior alveolar canal, nasal fossa or maxillary sinuses. Improper patient positioning may further contribute to image distortion. Even properly positioned and exposed panoramic radiographs cannot be used for direct bony measurements (not enough for implant placement) unless the magnification factor for the target area is predetermined. Predetermination of the magnification factor can be accomplished using a radiographic stent with ball bearings embedded in acrylic and imaged in the patient’s mouth [Figure 2].

**Lateral cephalogram**

Along with soft tissue profile of the patient, axial tooth inclination and dentoalveolar ridge relationship in the midline can be assessed.

**Limitations**

Provide dentist with cross-sectional dimension only at midline, image magnification and also contralateral side superimposition evident [Figure 3].[6-12]

**CT**

3D reformatting useful in augmentation process like sinus augmentation, uniform magnification, high contrast, definition, multiplanar views, 3D reconstruction, simultaneous study of multiple implant sites, also enables software analysis.

**Limitations**

Limited availability, the cost factor, high radiation risk, requires technical skill, lack of usefulness for implant-interface follow-up due to lack of metallic streak artefacts [Figure 4a and b].

**Dentascan imaging**

This imaging modality provides us with programmed formation, recollection, and display of the image, mandibular arch, the maxillary arch and cross-sectional and tangential/panoramic images of the alveolus enabling accurate preprosthetic treatment planning. Diagnostic template is necessary for determining the position and orientation of dental implants.

**Limitations**

Magnification of images, grayscale values, is limited, and the tilt of the patient’s head during the examination is critical.

**Interactive CT (ICT)**

It overcomes limitations of CT, also enables radiologist to transfer the image to the computer, so clinician can view the image on his own computer. Hence, 3D treatment can be planned according to patient’s anatomy and can be seen before surgery thus helping in determining the number and size of implants correctly according to density of bone at suggested sites. ICT is more relevant diagnostic technique when compared to conventional techniques for implant planning.

**Limitations**

Exact position of implants is difficult, tedious and time-consuming [Figure 5].

---

**Figure 2:** Panoramic radiograph showing five implants in mandibular anterior tooth region

**Figure 3:** Sagittal view showing soft tissue profile along with cross-sectional image

**Figure 4:** Computed tomography images, bone reconstruction showing as denta scanner (a), determination of alveolar bone height in maxillary anterior tooth region and distance from nasal fossa (b)
Implant imaging an update

**MRI**

In MRI, cortical bone can be clearly delineated from the cancellous bone. Vital structures such as nerves, vessels, and the floor and mucosa of the maxillary sinus are readily identified by the implant surgeon, exceptionally safe due to the absence of ionizing radiation, high image quality.

**Limitations**

High capital and running costs with lack of availability have been a significant barrier to the use of MRI for implant assessment.\(^{13,14}\)

**CBCT and multidetector CT**

It allows the surgeon to have an accurate information of implant site, in edentulous patient or when multiple implants are considered thus aiding in diagnosis and provides the dentist with controlled surgical plan, is used when conventional radiograph fails to provide the needed information.\(^{18}\) Assessment can be done in all three planes of space without image distortion, superimposition of structures, and differential magnification of the image based on geometry, also accurate location of anatomic landmarks as well as the height, width, angulation, and quality of alveolar bone for implant site. Also for case selection and a postsurgical evaluation to assess implant’s position in the alveolus.

**Limitations**

Increased susceptibility to movement artifacts and metallic restoration may lead to streak artefact, in CBCT no standard grayscale system present, so universality is questionable [Figure 6a-c and Table 3].\(^{15-19}\)

**Complications**

Failure of the implant to osseointegrate with adjacent bone is the most common mishap leading to implant mobility, post-operative infection (perimplantitis) [Figure 7a-c].

**Conclusion**

Dental implantology is a rapidly expanding area of dentistry. The imaging modalities range from 2D projections to complex 3D imaging. The 2D modalities are readily available, cost effective with least radiation exposure, but have limitations of magnifications and superimpositions and so clinician will not be able to develop a 3D perspective of patient’s anatomy with a single image. However, in complex cases, more extensive and advanced radiographic evaluation is needed.\(^{10}\) Hence, cross-sectional imaging is increasingly considered essential for optimal implant placement, important roles in pre- and postoperative evaluation of the implant patient especially in complex reconstructions and multiple implants.\(^{11,12}\)

Figure 5: Interactive computed image on the computer screen

Figure 6: Cone-beam computed tomography, sagittal view (a), mandibular arch (b), inferior alveolar canal on cross-sectional image (c)

Figure 7: (a) Saucerization, (b) perifixtural bone loss, (c) implant fracture
References


Table 3: Dose comparisons of dental imaging modalities

<table>
<thead>
<tr>
<th>Technique</th>
<th>Single periapical film</th>
<th>Full mouth radiographic survey</th>
<th>Panoramic</th>
<th>CT maxilla</th>
<th>CT mandible</th>
<th>MRI</th>
<th>CBCT</th>
</tr>
</thead>
<tbody>
<tr>
<td>Effective dose (μsv)</td>
<td>10</td>
<td>150</td>
<td>26</td>
<td>104</td>
<td>761</td>
<td>0</td>
<td>20-70</td>
</tr>
</tbody>
</table>