

Implant Imaging

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ABSTRACT

Implants improve the quality of life for patients who are unable to keep their natural teeth, fix acute problems, and give patients the benefit of restorative improvements for a modern lifestyle. The greatest key to successful implant placement is accurate preplacement assessment. Imaging plays a pivotal role in preplacement assessment. Success of dental implant restorations is in part, dependent on adequate diagnostic information about the bony structures of the oral region. This article reviews the applications of different imaging technologies and their diagnostic contribution to presurgical evaluation, treatment planning and postoperative assessment of dental implants.

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INTRODUCTION

Dental implantology was pioneered in the 19th century. The introduction of dental implants has revolutionized the world of dentistry. Since the American Dental Association (ADA) endorsed the practice in 1986, the market for implant dentistry has grown rapidly and has been aided by technological advances. Beyond replacing teeth lost to injury, increased life expectancy and esthetic concerns accelerate the wide acceptance of implantology.¹

Implants improve the quality of life for patients who are unable to keep their natural teeth, fix acute problems and give patients the benefit of restorative improvements for a modern lifestyle. They have gained immense popularity as they permanently restore the lost tooth structure without interfering with oral function or speech or compromising the self-esteem of the patient.

The greatest key to successful implant placement is accurate preplacement assessment. Imaging plays a pivotal role in preplacement assessment. Success of dental implant restorations is in part, dependent on adequate diagnostic information about the bony structures of the oral region. In order to accurately plan an implant procedure it is essential to obtain information regarding the volume, quality, and the topography of the bone at a potential implant site. It is also important to determine the relationship of the proposed implant to important anatomical structures, such as nerves, vessels, teeth, nasal floor and sinus cavities at the implant site.² Acquiring this information usually requires some form of imaging, which may vary from simple two-dimensional

views, such as intraoral radiographs, to more complex views in multiple planes, depending on the case and the experience of the practitioner.³

The various imaging modalities include intraoral radiography (film-based and digital), panoramic radiography, computed tomography (CT), cone-beam computed tomography (CBCT), etc. Selection of the specific imaging technique should be based on its suitability for providing the diagnostic information required by the implant team (dentist, implantologist, radiologist) at different stages of treatment.⁴

This article reviews the applications of different imaging technologies and their diagnostic contribution to presurgical evaluation, treatment planning and postoperative assessment of dental implants.

IMPLANT IMAGING TECHNIQUES

Intraoral Periapical Radiographs

Periapical radiography provides a high-resolution planar image of a limited region of the jaws.⁵ These techniques are able to resolve more than 20 line pairs per millimeter, which is at least twice the resolving power of either digital intraoral imaging or extraoral radiography.⁶ Image quality is related to several factors, including the use of nonscreen films, short object-film distance, long source-film distance, tight collimation and controlled alignment of the film, object and imaging source.⁷

They afford evidence of the presence of pathosis, the approximate location of anatomic structures relative to the proposed site of implantation, such as the maxillary sinus and an estimate of the quality of trabecular bone (Fig. 1). Periapical radiography may be helpful in determining the approximate height of the alveolar bone, the distance of the proposed implant sites from key anatomic structures, and the quality of the recipient alveolar bone by means of trabecular pattern.⁶

Moreover, radiation exposure is less in periapical radiography, and accurate details are obtained. It is also easily available and can be used in any clinical setup.

Periapical radiographs may suffer from distortion and magnification. Millimeter radiopaque grids, sometimes used in endodontics, may be superimposed over the film before it is exposed but, are of little quantitative value and provide misleading information because, they lie on the film, and obscure the underlying anatomy and do not compensate for magnification.

The opposing landmark of available bone in implant dentistry is beyond lingual muscle attachments in the

mandible or beyond the palatal vault in the maxilla. As such, the image most often must be foreshortened to visualize the opposing cortical plate. As a result, the actual available bone height may be difficult to determine.⁸

The imaging field with periapical radiography is restricted and its reproducibility is limited. Moreover, this modality is of no value in depicting the buccolingual width of the edentulous ridge. Periapical radiography is more often used for single-tooth implants in areas of abundant bone height and width. The use of periapical radiographs in the edentulous patients is limited.⁹

In terms of the objectives of preprosthetic imaging, periapical radiography is:

1. A useful high-yield modality for ruling out local bone or dental disease.
2. Of limited value in determining quantity because the image is magnified, may be distorted and does not depict the third dimension of bone width.
3. Of limited value in determining bone density or mineralization (the lateral cortical plates prevent accurate interpretation and cannot differentiate subtle trabecular bone changes).
4. Of value in identifying critical structures but of little use in depicting the spatial relationship between the structures and the implant site.⁸

Direct digital intraoral imaging is emerging as an alternative to film-based radiography. Its advantages include rapid acquisition of images, their storage, retrieval and passage to remote sites. Direct measurements of height and width can be obtained. These radiographs can be easily sent to other operator sites, i.e. teleradiography.

The limitations of direct digital intraoral imaging are same as that of IOPA radiographs. Hence, its use is dependent on the operator's ability to manipulate image density and contrast to measure the bone density at specific sites and to use it further for treatment planning.¹⁰

Occlusal Radiograph

Occlusal radiographs are planar radiographs. Occlusal radiography produces high resolution images. Intraoral occlusal radiographs are capable of demonstrating almost the entire alveolar process of either the maxilla or the mandible (Fig. 2).

However, a true cross-sectional view in the axial plane, unobstructed by superimposition, is possible only in the mandibular arch. An additional disadvantage of this technique is that the mandibular occlusal radiograph at best describes the maximum width of bone, which is usually at the base of the jaw, and fails to show the medial and lateral extent of cortical bone delineating the alveolar process and the salivary gland fossa. The degree of mineralization of trabecular bone is not determined from this projection, and

the spatial relationship between critical structures, such as the mandibular canal and the mental foramen and the proposed implant site is lost with this projection.

As a result, occlusal radiographs are rarely indicated for diagnostic preprosthetic phases in implant dentistry.

Panoramic Radiography

The imaging technique should be able to assess normal anatomic structures from all perspectives, evaluate proposed sites for pathosis, indicate possible surgical paths of insertion, aid in postoperative evaluations, and provide diagnostic and treatment documentation. Panoramic radiography is one of the imaging modalities that will allow a practitioner to meet these goals.¹¹

A panoramic radiograph is useful in the diagnosis of gross pathosis within the jaws as well as the relation of anatomic structures, such as sinuses, canals, fossae and foraminae to the implant site (Fig. 3).

Some panoramic machines have varied and unreliable magnifications (25 to 30%). Magnification is more pronounced in posterior than in anterior areas (Fig. 4). This



Fig. 1: IOPA radiograph

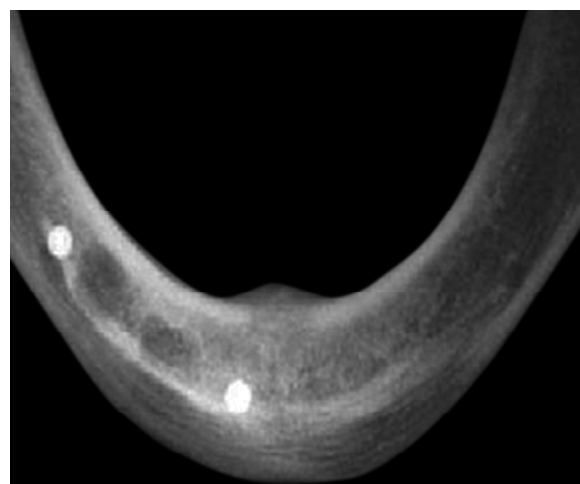


Fig. 2: Occlusal radiograph

may give a false sense that more bone exists between the crest of the alveolar process and the inferior alveolar canal, nasal fossae or maxillary sinuses. Improper patient positioning may further contribute to image distortion.⁷ Equalization of the vertical and horizontal magnification is achieved only for a limited zone that lies within a curved plane called the central plain of the image layer or the focal trough.

Predetermination of the magnification factor can be accomplished by using a radiographic stent with ball bearings embedded in acrylic and imaged in the patient's mouth. The diameter of the ball bearings in the area can be measured radiographically and compared with their actual diameter. Bone measurements can then be adjusted accordingly.

A major limitation of traditional panoramic radiography is its inability to generate cross-sectional images of the alveolar ridge.

Advantages

1. Opposing landmarks are easily identified.
2. Vertical height of bone initially can be assessed.
3. Can be performed with convenience, ease and speed.
4. Gross anatomy of the jaws and any related pathologic findings can be evaluated.

Shortcomings of panoramic imaging are as follows:

1. Does not demonstrate bone quality/mineralization.
2. Misleading quantitatively because of magnification and because the third dimension, cross-sectional view is not demonstrated.



Fig. 3: Panoramic radiograph

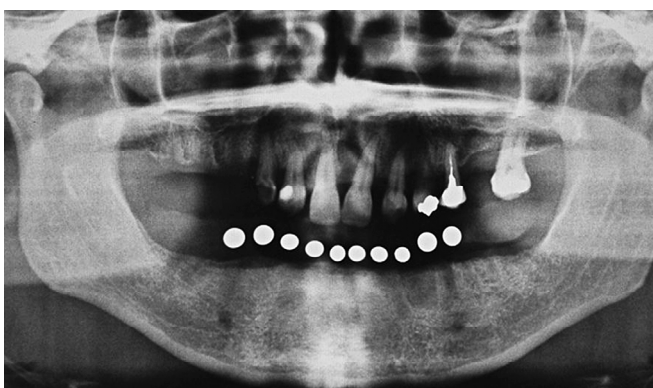


Fig. 4: OPG with unequal magnification



Fig. 5: Lateral cephalograph

3. Of some use in demonstrating critical structures but of little use in depicting the spatial relationships between the structures and dimensional quantification of the implant site.

Cephalometric Radiography

Lateral cephalometric or profile radiographs can be useful diagnostic aids in implant treatment planning. Pertinent information provided by these images include angulation, thickness and vertical bone height, in the midline, inter jaw skeletal relationships and the soft tissue profile (Fig. 5).

The advantages of lateral cephalometric radiographs for implant treatment planning are low costs, easy acquisition and ready availability.

The disadvantage is that the cross-sectional anatomic information is limited to the midline of the maxilla and mandible.

Conventional Tomography

In conventional tomography, the X-ray beam and film move with respect to each other, blurring out structures not in the desired thin imaging plane. In general, the more complex the tomographic motion, the more effective the blurring and the less the production of streaking artifacts.³

The advantages of conventional film tomography include moderate expense (compared with CT), uniform magnification, cross-sectional views available at any location and reproducible imaging geometry when used with a cephalostat. Some of the computer-aided machines also produce parasagittal tomograms perpendicular to the cross-sectional images.

The disadvantages of conventional tomography include limited availability (although this is rapidly changing as more dental schools and private practices add tomographic capabilities) and more time needed to produce the images than with standard panoramic radiography. Significant experience and training is necessary to interpret the images.

Conventional tomography is adequate where replacement of a single tooth or several teeth within a limited area is expected, and no significant anatomic variations exist.

Computed Tomography

It is an advanced imaging technique in which images are acquired digitally and subsequently reformatted into any plane, such as axial, sagittal or coronal. In CT implant imaging, multiple thin axial slices are obtained through the jaws, and then the data are reformatted with special software packages to produce cross-sectional and panoramic views (Fig. 6). Computer software designed for implant planning is also available to analyze the CT scans and to help in planning implant placement with electronically simulated fixtures.

The coronal sections of the ridge provide adequate information about the residual ridge. The residual ridge has been classified into four different types, based on the amount of bone structure remaining.¹² The clinical application is

different for different types of residual alveolar ridge. The treatment plan and the type of implant used vary as per the type of bone available.

The advantages³ of CT-based systems are as follows:

1. Uniform magnification.
2. A high-contrast image with a well-defined image layer free of blurring.
3. Easier identification of bone grafts or hydroxyapatite materials used to augment maxillary bone in the sinus region than with conventional tomography.
4. Multiplanar views.
5. Three-dimensional reconstruction.
6. Simultaneous study of multiple implant sites.
7. The availability of software for image analysis.

The disadvantages⁴ of CT include:

1. Limited availability of reconstructive software.
2. Expensive.
3. Higher doses of radiation compared with conventional tomography and CBCT.

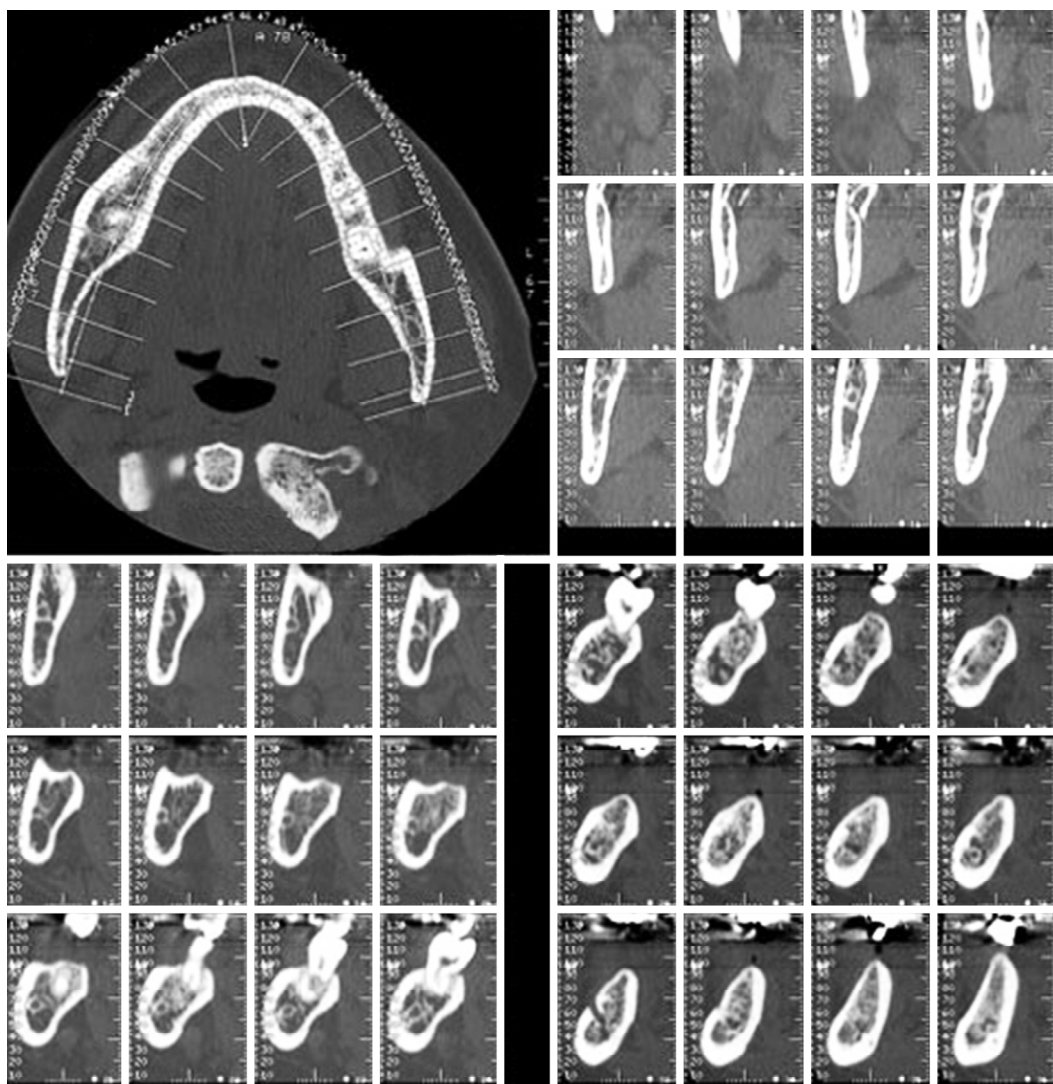


Fig. 6: CT reformatted with Dentascan

4. Lack of understanding of the dentist's imaging needs by the radiologic technologists and medical radiologists who acquire and interpret the CT images.
5. Lack of usefulness for implant-interface follow-up because of metallic streak artifacts.
6. Metallic restoration artifacts.

Tuned Aperture CT (TACT)

An alternative to film-based tomography and CT for dentoalveolar imaging is a method based on optical aperture theory, referred to as TACT. This technique uses information collected by passing a radiographic tube that can be fixed in a closed 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 three-dimensional matrix.

TACT offers a number of advantages because projection geometry can be calculated after individual exposures, problems of patient movement are also less significant and radiation doses are comparatively less. TACT imaging can efficiently identify the location of crestal defect around implant fixtures and natural teeth in addition to detecting subtle or recurrent decay.¹³

Cone Beam CT

Cone beam CT (CBCT) scanners are based on volumetric tomography, using a 2D extended digital array providing an area detector. This is combined with a 3D X-ray beam. The cone-beam technique involves a single 360° scan in

which the X-ray source, and a reciprocating area detector synchronously move around the patient's head, which is stabilized with a head holder. Software programs incorporating sophisticated algorithms are applied to these image data to generate a 3D volumetric data set, which can be used to provide primary reconstruction images in three orthogonal planes (axial, sagittal and coronal) (Fig. 7).

A CBCT scan, in combination with software modeling, can be used as a virtual planning environment to achieve the ideal placement of the prosthetics, occlusion and associated supporting implants, in a virtual environment.¹⁴

For each implant site, it can:

1. Determine bone height and width (bone dimensions) via 3D CBCT.
2. Determine bone quality with comparative density analysis in 3D.
3. Determine the long axis of alveolar bone.
4. Identify and localize internal anatomies, such as nerves and sinus cavities.
5. Determine jaw boundaries.
6. Identify pathology in 3D scale and scope.
7. Transfer of radiographic planning information.
8. Communicate radiographic diagnostic and planning information.¹⁵

CBCT has helped the operator to overcome the shortcomings and disadvantages of the various other techniques.

CBCT can also be coupled with surgical templates and virtual implant placement software to achieve accurate implant placement.

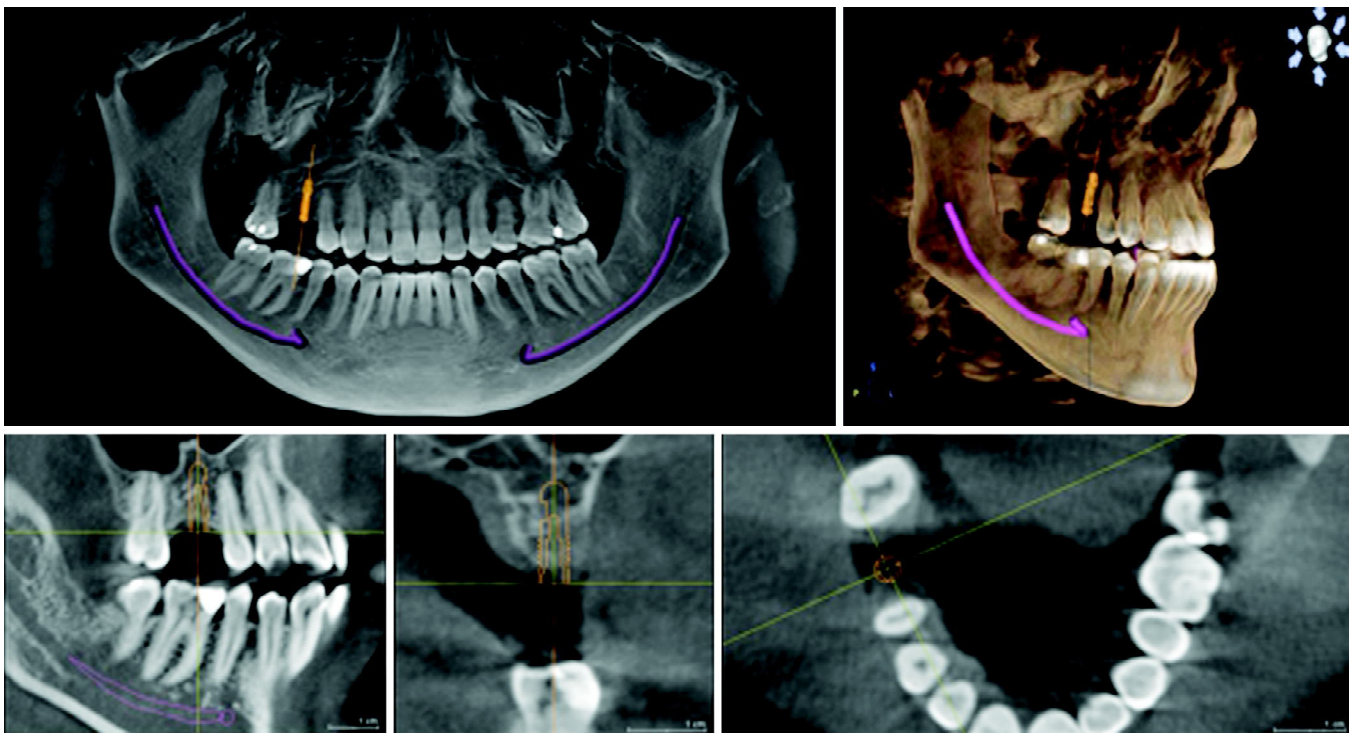


Fig. 7: Cone beam CT

Magnetic Resonance Imaging

Magnetic resonance imaging (MRI) is a three-dimensional imaging technique with an electronic image acquisition process, and a resulting digital image. The image sequences used to obtain MRI can be varied to obtain fat, water or balanced imaging of the patient's anatomy.

An MRI is a quantitatively accurate technique with exact tomographic sections and no distortion. An MRI is used in implant imaging as a secondary imaging technique when primary imaging techniques, such as complex tomography, CT fail. Failure to differentiate the inferior alveolar canal may be caused by osteoporotic trabecular bone and poorly corticated inferior alveolar canal. An MRI visualizes the fat in trabecular bone and differentiates the inferior alveolar canal and neurovascular bundle from the adjacent trabecular bone.

Double-scout MRI protocols with volume and oriented cross-sectional imaging of the mandible produce orthogonal quantitative contiguous images of the proposed implant sites. Oriented MRI of the posterior mandible is dimensionally quantitative and enables spatial differentiation between critical structures and the proposed implant site.

An MRI is not useful in characterizing bone mineralization or as a high-yield technique for identifying bone or dental disease.¹⁶

CONCLUSION

Diagnostic imaging provides adequate information of the anatomy and structure of implant site. This information aids in selection of appropriate implant, reduce undue complications thus ensuring successful implant placement.

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 to the type and number of implants, location and surrounding anatomy. As in the case of all imaging modalities, appropriate selection criteria must be applied individually to each patient.

CBCT should be the method of choice, as it provides all diagnostic information necessary for successful implant placement. Many companies have come with high resolution cone beam machines, e.g. XG 3D by Sirona, ProMax 3D by Planmeca and Newton.

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