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Radiographic imaging in implant dentistry

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Abstract
Intraoral periapical, panoramic, and cephalometric radiographs may best be used during the initial phase of patient evaluation. Individually or as a group they provide a radiographic overview of the patient's oral condition, including the presence or absence of pathoses. However, these techniques do not provide an accurate determination of the quality and quantity of available bone, because the images they produce are of unpredictable magnification and represent only the facial aspect of the maxilla and mandible. Quantitative and qualitative analyses of bone can be conducted at implant site by using CT scan. MRI can be used to locate the exact vital structures. The recent technology used for dental implant imaging is CBCT, as it provides the rapid acquisition of data with little radiation exposure. This article includes brief descriptions of the technical principles of each imaging modality in implant dentistry.

Keywords: Radiographic imaging, radiographs, CT scan, MRI

Introduction

Radiology is important in dentistry and have role in treatment planning, monitoring disease progression and in assessing treatment efficacy. The utilization of diagnostic imaging in implant dentistry has changed tremendously over the years. Various imaging techniques are used to evaluate bone quality, quantity, and anatomic structures in location to the proposed implant sites. There are many factors that play a task within the success of implant dentistry. One key factor is Radiographic imaging, like periapical, occlusal, panoramic, and motion tomography but the knowledge is predicated on bidimensional geometric projections [1].

The features of ideal radiographic imaging should be: The ability to see the implant site within the mesiodistal, buccolingual, and superioinferior dimensions; they should have reliable, accurate measurements; a capacity for evaluation of trabecular bone density (bone mineral density, BMD) and cortical thickness, reasonable access and price to the patient and minimal radiation risk [2].

Conventional dental x-rays have diagnostic value; however, they're ultimately limited as 2D depictions of 3D structures. A number of the drawbacks of those techniques include superimposition, poor visualization of other anatomic structures, and distortion [3]. Currently, the most accurate technique for preoperative evaluation of dental implantation is dental CT. Dental CT can demonstrate the number of bones in three dimensions, the situation of important adjacent anatomic structures (eg, mandibular canal, dental inferior nerve, incisive foramen, mental foramen, maxillary sinus), and therefore the quality of obtainable bone with minimal geometric distortion.

Anatomic considerations

Table 1

Important structures in the maxilla	Important structures in the mandible
Alveolar process of maxilla	Mandibular or inferior alveolar canal
Maxillary sinuses.	Mental foramen
Nasal fossa	Incisive canal
Nasopalatine foramen.	Mylohyoid ridge
Nasopalatine canal	Genial tubercules

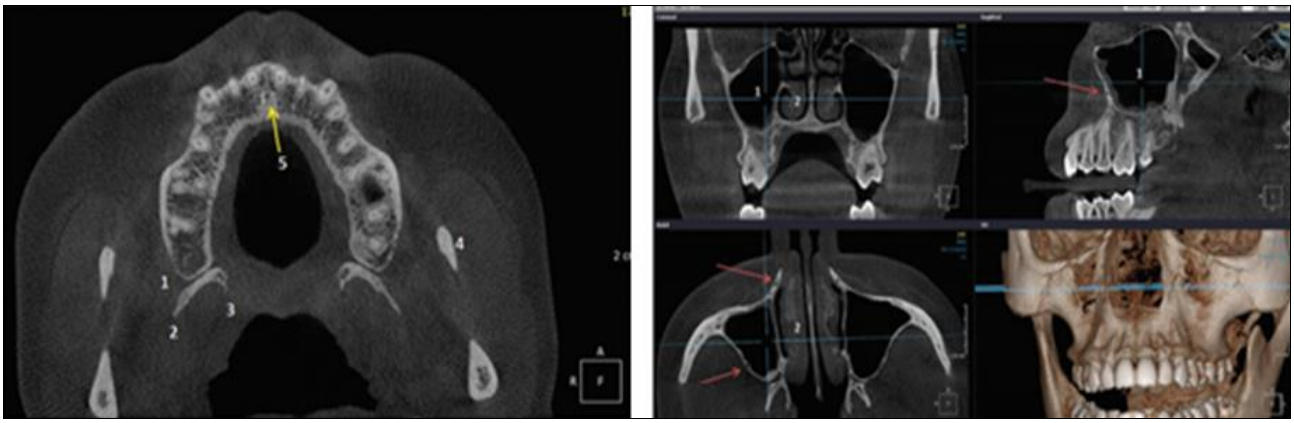


Fig 1: CBCT image at the level of cervical regions of maxillary teeth showing pterygomaxillary fissure, lateral pterygoid plate, medial pterygoid plate, ramus of mandible, nasopalatine canal, maxillary sinus, inferior nasal turbinate, zygomatic body, zygomatic arch

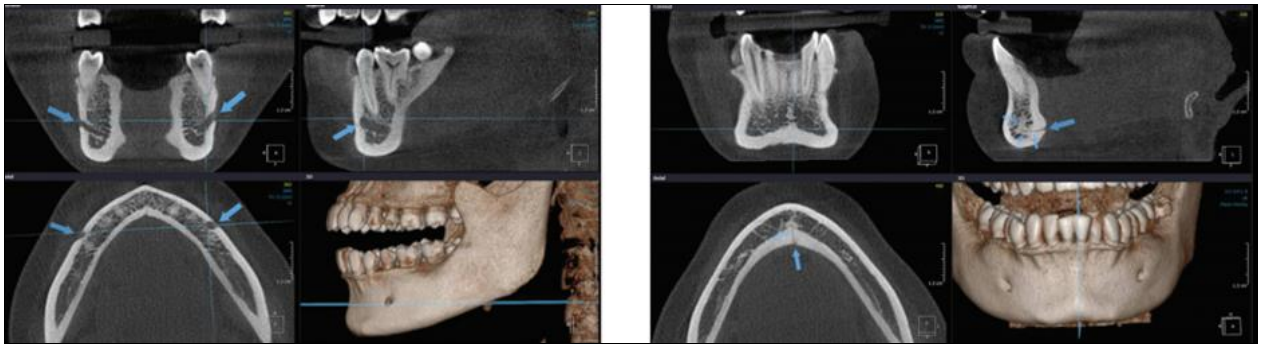


Fig 2: CBCT image shows right and left mental foramina. Clockwise from top left - coronal, sagittal, and axial sections showing the Position of mental foramina (arrows). Left mental foramen seen on image (bottom left). Mandibular lingual incisive canal seen in mandibular midline region. Clockwise from top left - coronal, sagittal, and axial sections showing the position of incisive canal (arrows).

Dental Scanning

The status and quality of the bone are among the most significant parameters for the surgeon to consider when evaluating a potential implant site prior to surgery. A range of imaging modalities can be used to assess bone support, mass, and height. Traditional x-ray techniques including periapical, occlusal, and panoramic radiography are straightforward, low-cost, and widely utilized, yet the information they provide may be inadequate. High-resolution dental CT [4, 5] can generate panoramic, cross-sectional, and three-dimensional reformatted images of the alveolar bone and adjacent structures providing accurate information about bone height and width of the alveolar ridge.

Classification of radiographic imaging techniques [6]

Table 2

Phases	Name	Objectives
Phase 1	Presurgical	All surgical and prosthetic information required to evaluate the quantity and quality of bone, including height, width, and length for optimum implant selection, localization of vital structures, prosthetic demands, potential implant sites, and the presence or absence of disease.
Phase 2	Surgical and intraoperative	To evaluate the surgery sites during and immediately after surgery, assist in the ideal position and orientation of dental implants, evaluate the healing and integration phase of implant surgery, and make sure that abutment position and final prosthesis fabrication are correct.
Phase 3	Postoperative	To access the long-term maintenance, integration, and function of the implants, which includes the evaluation of the implant complex and surrounding crestal bone levels.

Imaging Modality

Basic classification of image modality consists of as analog or digital and either two or three dimensional.

Types of image modality

Table 3

S.no	Planar two dimensional	Quasi three dimensional	Three dimensional
1.	Periapical Radiography	Panaromic Radiography	CT
2.	Occlusal Radiography	X Ray Tomography	CBCT
3.	Cephalometric Radiography	_	MRI
4.	-	-	Interactive CT

Periapical Radiography

Intraoral periapical radiographs (IOPAR) are generally used for the presurgical evaluation of implant site. Also used commonly due to its simplicity, significantly lower cost, Less radiation exposure and easy availability in a dental clinical set-up [7]. Basically, it consists of paralleling and bisecting angle techniques [8].

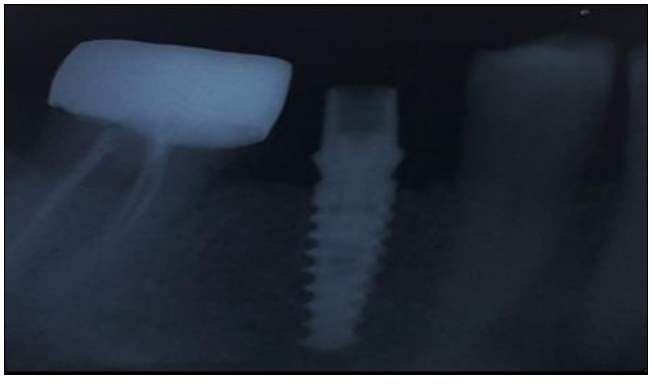


Fig 3: Periapical Radiography

Advantages
- reduced skin dose
- Minimal magnification with proper technique
- High resolution
- Inexpensive

Disadvantages
- Distortion and magnification
- Minimal site evaluation
- Difficulty in film placement and use of film holder is painful especially in edentulous patient
- Lack of cross sectional imaging
- Buccolingual width can not be measured
- Bone density can not be established

Indications
- presurgical implant site evaluation
- Alignment and orientation during surgery
- Post prosthetic stage evaluation

Digital Radiography

The digitalization in dental radiography came in 1987 with the first digital radiography system called radiovisiography (RVG), by Dr. Francis Mouyen [9]. RVG is a multicomponent system. It allows an operator to capture colored images from a patient mouth via an intraoral camera and transfer of this image to a computer. The images can be zoomed, rotated or edited by the computer. Further manipulation like image enhancement, contrast stretching, and reversing also possible [10].

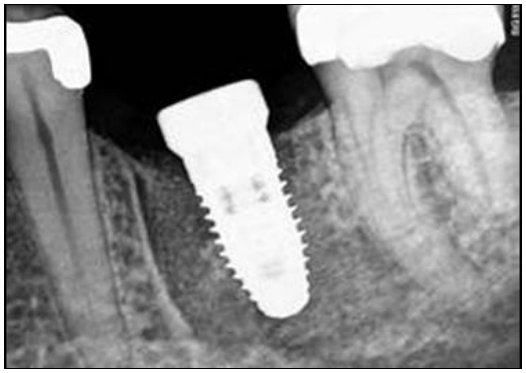


Fig 4: Digital Radiography

Occlusal Radiography

Occlusal radiographs are planar radiographs created by positioning the film intraorally parallel to the occlusal plane, with the central x-ray beam perpendicular to the film for the mandibular image and oblique to the film for the maxillary image (typically 45 degrees). Occlusal radiography generates high-resolution planar images of the body of the mandible or the maxilla. Occlusal radiographs of the maxilla are inherently oblique and so deformed. Therefore, they have no use in measurement of quantity and quality of bone around the implant placement. Occlusal radiography can evaluate structures such as the maxillary sinus, nasal cavity, and nasopalatine canal. The projection of a mandibular occlusal radiograph is less distorted than that of a maxillary occlusal radiograph. (11) Because the occlusal radiograph of the mandible is an orthogonal projection.

Advantages
- Low radiation dose
- High resolution
- Inexpensive

Disadvantages
- Spatial relation can not be established between critical structures, such as the mandibular canal and the mental foramen, and the proposed implant site
- Bone density can not be evaluated

Indications
- Of little value

Cephalometric radiography

The skull is oriented to the x-ray device and the image receptor by a cephalometer, which fixes the position of the skull with projections into the external auditory canal. The cephalometric imaging devices results in a 10% magnification of the image with a 60-inch focal object and a 6-inch object-to-film distance [8]. Cephalometric radiography is a radiographic technique that allows for a determination of image magnification. As a result, measurements may be obtained from these images with a known degree of accuracy [12].

Advantages
- Provide information of inclination of the maxillary and mandibular alveolar process and on their vertical and facial-lingual dimension in the midsagittal planes
- The cross-sectional view of the alveolus demonstrates the spatial relationship between occlusion and esthetics with the length, width, angulation, and geometry of the alveolus and is more accurate for bone quantity determinations.
- Low magnification
- Relation of lingual cortical plate to skeletal structure can be estabilished

Disadvantages
- Image information limited to midline, the location of anterior jaw structures relative to the plane of the image receptor
- Reduced resolution

Indications
- Used in combination with other radiographic techniques for anterior implants
- In the symphysis region ,before this bone is harvested for ridge augmentation.

Panoramic radiography

Panoramic radiography widely used technique in dentistry. However, when dentist is planning implant therapy, it should be always kept in mind that the panoramic radiograph may show 10-30%magnification of hard tissue structure. Implant companies often market magnified overlays with a present 25% magnification for evaluation of an implant size that are placed on a panoramic film for comparison with vital structure positions. However

Panoramic radiography can't be used as the only presurgical assessment of dental implant treatment planning. Because of the inherent disadvantages of panoramic radiographs, most clinical studies verify the inaccuracies of direct in measurements. For correct positioning of the edentulous patient, panoramic radiograph should be made with the patient's dentures in place and thus take advantage of the incisal guide [13, 14].

Fig 5: Panoramic radiography

- Easy identification of opposing landmarks
- Initial assessment of vertical height of bone
- Convenience, ease, and speed in performance in most dental offices
- Evaluation of gross anatomy of the jaws and any related pathologic findings

Disadvantages

- Distortions inherent in the panoramic system
- Errors in patient positioning
- Does not demonstrate bone quality
- Misleading measurements because of magnification and no third dimension
- No spatial relationship between structures

indications

- multiple implant site
- alignment and orientation during surgery
- post prosthetic stage evaluation

Conventional tomography

Cross-sectional tomography has been successfully applied to dental implant diagnostics [15]. Sharp visualization of structures in the focal plane, while blurring all other structures is achieved by working with different tomographic movements in the linear, circular, spiral, elliptical, and hypocycloidal planes [16, 17]. For radiographic visualization of the mandibular canal, cross-sectional imaging provides the best information.

Advantages

- It can determine spatial relationship between the critical structure and implant site
- Help in quatification of geometry of bone

Disadvantages

- For the assesment of greater number of site ,this technique found to be too time consuming .

Indications

- Assesment of height &thickness in cases of alveolar bone atrophy
- Assesment of positions &states of structures critical for adequate implant

Computed tomography

The CT scan was founded by Sir Godfrey Hounsfield. (18) Computed tomography was originally developed for examination of soft tissues particularly brain. It computed which cross-sectional tomographic images are obtained digitally and later image data can be reformatted into any plane that is axial, sagittal or coronal [19].

Advantages

- Negligible magnification
- Various views
- Three-dimensional bone models
- Interactive treatment planning
- Cross-referencing
- Elimination of superimpositions.
- It also allows distinction of opacity differences between two tissues (ie, contrast resolution), and further image projections or planar reformations can be performed.(20)

Indications

- Assessment of height and thickness in cases of alveolar bone atrophy
- Assessment of the positions and states of the structures critical for adequate implant placement (eg, inferior alveolar canal, location of the neurovascular bundle and the incisive and mental foramina, of the maxillary sinus, floor of the maxillary sinus, nasal fossa)
- Diagnosis and treatment in maxillofacial surgery;
- Examination after placement of implants and bone grafts (21)

Contraindications

- Claustrophobia
- Parkinson's disease
- Tremors and tics disabling conditions that might cause a patient to be uncooperative.23)

Image Development

An image matrix with discrete image or picture elements called voxels describes a digital three-dimensional image. A digital three-dimensional image is defined by its depth and thickness in addition to its width and height in pixels (i.e., 512 512). An imaging volume or three-dimensional

characterization of the patient is produced by contiguous images, which produce a three-dimensional structure of volume elements (i.e., CT, MRI, and interactive computed tomography) [6] Each voxel and pixel displayed is characterized by a numerical value that represents the density of the tissues. This is termed the CT number. Each CT number that makes up the pictures is assigned a certain shade of grey or density value. The final computed tomography image depends on the pixel (two-dimensional [2D]) and the voxel (three-dimensional [3D]) size [23, 2].

Bone assessment

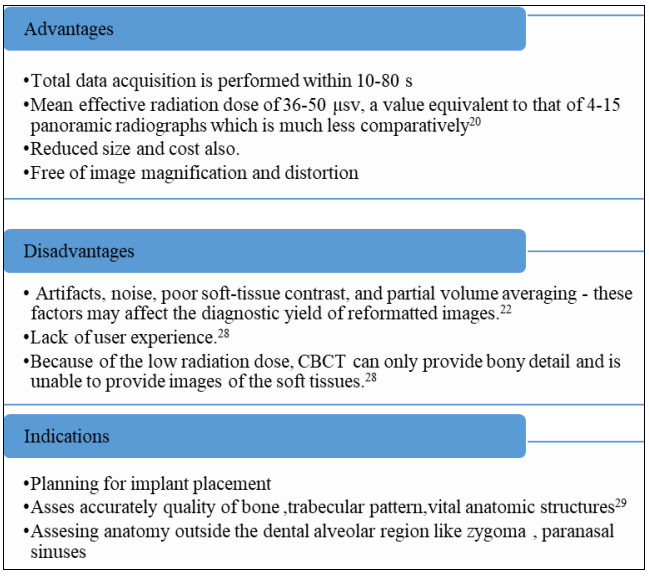
Successful implant placement and Osseo integration requires [25]

On either side of the fixture, 11.5 mm of bone

- Between the base of the fixture and surrounding structures such as the nasal fossa, maxillary sinus floor, and mandibular canal, there should be 1-2 mm of bone.
- Determination of ridge angulation with relation to the ridge's vertical axis.
- Occlusal force vector parallel or nearly parallel to the vertical axis through the ridge acting on the implant fixture.

Cone-Beam Computed Tomography

This is advanced type of tomography and termed as cone-beam computed tomography (CBCT). The introduction of CBCT has foreshadowed a shift from a 2D to a volumetric approach in maxillofacial imaging. It includes different types of terms like technical data acquisition, reconstruction, image display, and image interpretation [26, 27].



Interactive CT

Most important progression in CT is interactive computed tomography [ICT]. In this type of CT, the information transfer from radiologist to practitioner in the form of a computer file. The advantages are, practitioner uses specialized software to measure the bone quantity and bone quality at implant site and also allow the clinician to measure proximity of any vital structure to the implant site. [30, 31] In Interactive CT a 3D treatment plan combined with patient's anatomy is devised and clinician performs electronic surgery on computer before actual implant surgery [32, 33].

Magnetic resonance imaging

Magnetic resonance imaging (MRI) was invented by Lauterbur. In dental implantology MRI have recent origin. Mainly it is used for soft tissue imaging such as location of inferior alveolar origin. Studies have shown that geometric accuracy of MRI is comparable to CT and it is an acceptable imaging modality for dental Implantology [33]. Ferromagnetism is the phenomenon related to MRI which results in production of artifacts in the image if the components of implant are ferromagnetic in nature. This is the reason which limits the use of MRI as an imaging modality after implant placement [30]. There are some limitations related to MRI like exposure of dental implant to MRI may result in heating of implant which may interfere with osseointegration [34, 35].

Tuned aperture computed tomography (TACT)

TACT stands for tuned aperture computed tomography, which is a new technology that can be used instead of film-based computed tomography. This method creates a picture by sending a radiography beam through an object from various angles. TACT uses several small radiographic tubes which are fired in close sequence and produce a single 3-dimensional image from the data collected by the sensor. [36, 37] Localization of bone disease, anatomical structures and abnormalities at implant site is much easier with TACT. In dentistry TACT is being used to identify crestal defect around implant in addition to early detection of subtle decay [31, 33].

Conclusion

With the outstanding imaging modalities that exist today, one can improve the success of implant dentistry. Accurate implant imaging modality selection is depending on the type and number of implants, location of the implant, and surrounding anatomy. Before choosing the best imaging approach for each patient, adequate selection criteria must be applied. There are two important factor one is cost and other one is exposure dose must be evaluated carefully during choosing implant imaging. Although CBCT is the current imaging modality of choice for pre-implant bone evaluation, CT is still used for this purpose due to its wider availability. Because superimposition and distortion are reduced, this technology outperforms traditional x-ray procedures. This non-invasive and fast method provides accurate information about the positions of important structures to allow one to determine the implant required.

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