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Implant Imaging

Rachele Vishanti
Undergraduate Student, BDS, Saveetha Dental College, Tamil Nadu, India
Dr. Gururaj Rao
Senior Lecturer, MDS, Department of Prosthodontics, Saveetha Dental College, India

Abstract:
Dental implants are gaining popularity amongst patients as a suitable form of replacement of missing teeth. In recent times, it has become a routine treatment plan in many dental practices. Appropriate treatment planning is required to ensure a successful outcome. Hence, radiology plays a vital role in providing information to the clinician so that a proper diagnosis and treatment modality could be planned out. There are various imaging techniques that are used. The most widely used techniques include intraoral periapical radiography, panoramic radiography, computed tomography and cone beam computed tomography. This article focuses on the advantages and disadvantages of each technique.

Key words: *Dental implants, periapical radiography, panoramic radiography, computed tomography, cone beam CT*

1. Introduction

Dental implants have revolutionized the treatment option for treating partially and completely edentulous patients and have gained popularity over the past decade. Successful placement of dental implants relies on meticulous treatment planning therefore it is important for a dentist to be able to place an implant in the oral cavity with a high degree of precision and accuracy. Radiology plays an important role in assessing the quality and quantity of the local bone and also provides information that enhances the success of the various stages of the procedure[1]. The radiographic image helps the dentist identify problems such as cysts, retained roots, infections in the mandible or maxilla along with the severity, type and location of the region that cannot be obtained by palpation thus making treatment planning easier[2].

Periapical radiographs and conventional dental panoramic tomography were the most important imaging modalities in the past. However, these being 2-dimensional techniques, do not provide a complete outlook on the patient's anatomy and have their geometric limitations. Panoramic radiographs also have a resolution and sharpness that are less than that of a periapical radiograph. Despite these shortcomings, it is still used as it is readily available and relatively inexpensive[3].

To overcome these limitations, newer techniques have been developed mainly to provide 3-dimensional information of the patient's anatomy. The latest technology includes the use of computed tomography (CT) and cone beam CT. This computer-assisted technology gives the dentist a realistic view of the anatomy of the jaw which would in turn help in accurately devising a treatment plan suitable for the patient[4]. This paper provides an overview of the advantages and disadvantages of the various radiological modalities and techniques available with respect to dental implants.

2. Role of Imaging in Treatment Planning

Radiographic imaging may provide the dentist with a silhouette of the entire jaw or a specific region in the mandible or maxilla with the complete anterior and posterior views over the vertical or horizontal axis in 2-dimension or preferably 3-dimensions. The better the resolution and the sharper the image, the easier it is for a dentist to work with utmost precision. This will enable the dentist to visualize the region where the implant is to be placed along with the bone height, width and the location of vital anatomical structures around that region. Radiographs also provide the quality and quantity of the bone along with the proximity of neurovascular bundles, foramine or air spaces. Naturally, while placing an implant, the dentist must take care that it is placed away from the neurovascular bundle and other vital tissues to avoid any kind of complication[5].

The objectives of diagnostic imaging depend on various factors. This includes the amount and type of information required and the time period of the treatment rendered. For implant placement to be a successful, there should be 1 - 1.5mm of bone on either side and 1 - 2mm of bone between the base of the fixture and adjacent vital structures such as nasal fossa, floor the sinus and mandibular canal[5]. There are many factors that play a part in deciding which imaging modality is to be used. Normally, panoramic radiography is done to begin with. This provides a complete image of the jaw along with the anterior and posterior regions of the mandible and maxilla[5]. But if the panoramic radiography doesn't provide enough necessary information, a periapical radiograph is advised to get more details with accuracy. However, if both fail, a Computed Tomography (CT) or Cone Beam Computer Tomography (CBCT) must be used to get all possible information accurately.

3. Imaging Modalities

The selection criterion for a diagnostic imaging technique depends on the patient's clinical requirements. The technique selected should provide maximum information about the respective region and should possess the least radiologic risk. The ideal technique should allow the dentist to visualize the region considered for implant placement in the mesiodistal, buccolingual and superioinferior dimensions. It should also allow accurate measurements and have the capacity to evaluate trabecular bone density and cortical thickness[3, 5]. The imaging modalities employed can be described as either analogue or digital and two-dimensional or three-dimensional. Analogue imaging techniques are the periapical, occlusal, panaromic and lateral cephalometric radiographs that are two-dimensional systems. Digital imaging techniques include magnetic resonance imaging, computed tomography and cone beam CT which are three-dimensional systems[6].

4. Periapical Radiography

Intraoral periapical radiography provides images of perhaps the greatest details of any imaging tecnique. It is commonly used in the initial stages of planning to detect the presence of any pathology, the approximate location of the anatomic structures and to estimate the quality of the trabecular bone[6]. It provides an image with better sharpness and thus can be used to accurately obtain the measurement along the horizontal direction, specifically the proximity of the adjacent roots making it easier to place implants with increased precision without affecting the vital structures[2].

Certain guidelines have to be followed when using the periapical radiograph. The paralleling angle technique has to be used or else an image with foreshortening and elongation will be created. Periapical radiographs are obtained by placing the film intra-orally parallel to the body of the alveolus with the central beam of the x-ray device placed perpendicular to the alveolus at the region of interest. This produces a lateral view of the alveolus with increased sharpness, minimal magnification and negligible distortion[6,7].

However, foreshortening occurs when the x-ray beam is perpendicular to the film but the object is not parallel to the film. Elongation occurs when the x-ray beam is oriented perpendicular to the object but not the film[3]. The image obtained can be magnified with a lens or can be digitally enhanced on a computer screen for a better understanding of the region of interest[2].

5. Advantages of Periapical Radiography Include[2, 7]

- It is used for single tooth implants in regions ofabundant bone width in the preprosthetic phase.
- Assessment ofperi-implant bone resorption during follow up
- Linear measurements in vertical and horizontal directions are accurate if paralleling technique is used to prevent image distortion
- Readily available
- Relatively inexpensive
- High quality
- Low radiation exposure.

6. Disadvantages of Periapical Radiography Includes[2, 7]

- Only a small area of the jaw is visible in each image
- Cross-sectional view of the alveolar process is not provided
- Decreased value in determining bone density or mineralization
- Limited value in determining bone quantity as the image maybe be distorted since it is magnified and does not depict the third dimension of bone width.

7. Panoramic Radiography

Panoramic radiography is vital for the initial evaluation of bone dimensions and detecting pathological conditions in treatment planning. Panaromic radiography is a curved plane tomographic radiographic technique used to depict the location and dimension of the lower one half of the maxillary sinus, nasal cavity, inferior alveolar canal and mental foramen in a single image. Although the image produced by the panoramic technique is relatively clear, it is often difficult to position the maxilla and mandible of edentulous patients so that both fall within the designed focal trough of the panoramic x-ray machine. This leads to distortion and magnification especially in the anterior region which can be up to 25%. Magnification varies to a greater extent in the horizontal direction (16%) than in the vertical direction (10%) due to the focus of projection. In the vertical plane, the efficient source of projection is the focal spot on the x-ray tube whereas in the horizontal plane, it is the rotational centre of the x-ray beam. Thus the variation in the horizontal

plane is because of the changing distance between the rotational center and the film and the changing rate of movement of the film to that of the x-ray beam. This problem results in a linear measurement error of approximately 3.0mm. However, when the magnification factor can be determined, these panoramic images have been shown to be reasonably accurate (within 1mm) for assessing the distance between the crest of the ridge and the superior border of the inferior alveolar canal[1, 2, 6].

Information obtained from panaromic radiography must be utilized aptly as the linear measurements do not tend to be accurate. Vertical measurement are unreliable because of foreshortening or elongation of the anatomic structures since the x-ray beam is not perpendicular to the long axis of anatomic structures or the film plane. The negative vertical angulations of the x-ray beam also may cause lingually positioned objects to be positioned superiorly on the film which may result in overestimation of the vertical bone height. There are several ways to avoid these problems, the most common being the usage of acrylic surgical stents containing metal balls of known dimensions. However, this technique does not overcome all problems, including lack of cross sectional imaging[2, 3, 6].

8. The Following Are the Advantages of Panoramic Radiography[1, 7]

- Easy identification of opposing landmarks
- Easy assessment of vertical bone height
- Preliminary estimations of crestal alveolar bone and cortical boundaries can be made
- Performed with convenience, ease and speed
- Gross anatomy of the jaws and any related pathology can be evaluated

9. Shortcomings of Panoramic Radiography Include[2, 7]

- Assessment of hard tissue morphology, bone density and quality is difficult because of the multiple overlapping images of other structures onto the jaws
- Does not provide information regarding the buccolingual cross-sectional dimension or inclination of the alveolar ridge
- Inaccurate assessment of mesiodistal distance due to inappropriate patient positioning and/or individual variations in jaw curvature
- Does not depict the spatial relationships between the structures and dimensional quantification of the implant site

10. Computed Tomography (CT)

Panoramic radiography and periapical radiography have always been in use for planning, diagnosing and restoring dental implants to asses bone anatomy for several decades. These techniques had their own shortcomings varying from magnified and distorted image to unreliable measurements of the horizontal and vertical directions of the region of interest in the mandible and maxilla. However, Computer Tomography (CT) has been proven a boon these days since it overcomes all the shortcomings of the older techniques and also provides detailed and more accurate information of the region of interest especially in the posterior region of the jaw for more complicated cases[2].

A computer tomogram is a digital image of the tissue slice generated mathematically by multiple exposure of an x-ray beam at various angle of the respective tissue to create a tomographic section. The CT unit is aligned at right angles to the long axis of the patient's body and is referred to as axially oriented slices. The axial slices should be oriented parallel to the inferior border of the mandible for mandibular imaging. For maxillary imaging, the axial slices should be oriented parallel to the hard palate[2]. These axial images are thin (1-2mm) and overlapping resulting in approximately 30 axial images per jaw[6].

CT has several advantages over conventional radiography. The first being, it eliminates the superimposition of structures that are not of interest. Secondly, the differences between tissues that differ in physical density less than 1% can be distinguished because of the inherent high contrast resolution of CT. Third, data from a single CT imaging procedure, consisting of either multiple contiguous one helical scan, can be viewed as images in the axial, coronal or sagittal planes or in any arbitrary plane depending on the diagnostic task. This is called multiplanar reformatted imaging. Due to difficulties in positioning the patient and metallic artifacts from dental materials, direct images are problematic in the coronal plane. Therefore, special software programs have been developed to help reformat the original data from axial CT scans into the sagittal and coronal planes or any arbitrary plane. The reformatted CT image thus provides the cross sectional and tangential or panoramic view of the alveolus in 3-dimension. It can be used with computer programs to digitally magnify and measure the bone area. Also it provides a cross section of the buccolingual width of the mandible and maxilla in 3-dimension with the proximity of neurovascular bundle thus helping greatly in visualization of the implant site. The cross sections and panoramic images are spaced roughly 1mm apart for the convenience of treatment planning[3].

The individual element of CT image is called a voxel which has a value referred to in Hounsfield units[1]. A voxel describes the density of the CT image at that point. The computer assigns numbers to voxels based on attenuation values, which are represented by small squares called pixels, each of which has a specific grey value in two-dimensional images on film or video monitor. Multiple pixels create a high contrast image that has a magnification error less than 6%. The density of structures in the region is absolute and can be used to differentiate the various tissues in the region and also to characterize bone quality. Using CT image, the bone width and height can be measured from point to point with great accuracy. The reformatted images obtained are magnified very slightly with an error ranging from 0.5mm to 2mm as compared to other radiography techniques which have a high error factor[2]. Thus, it is possible to select the implants of proper length and diameter by referring to the CT image.

11. The Advantages of CT Based Systems Include[6]

- Uniform magnification
- High contrast image with well-defined image layer free blurring
- Easier identification of bone grafts or hydroxyapatite materials used to augment maxillary bone in sinus region
- Multiplanar views
- Three-dimensional reconstruction
- Simultaneous study of multiple implant sites
- Availability of soft tissue for image analysis

12. The Disadvantages of Include[6]

- Limited availability of reconstructive software
- Higher dose of radiation
- May require the need of a radiologist to interpret the results
- Lack of usefulness for implant interface follow-up because of metallic artifacts
- Expensive

13. Cone-Beam Computed Tomography (CBCT)

To overcome the shortcomings of CT, the Cone-Beam Computed Tomography (CBCT) was developed. As the name implies, it is a medical image acquisition technique in which a cone shaped x-ray beam is centered on a 2 Dimensional detector. A series of 2 dimensional images are produced by the rotation of the source-detector system around the object. The resultant image can be reconstructed in 3 dimensions using the modification of original cone-beam algorithm developed by Feldkamp et al[8]. The first commercial CBCT that was introduced into the market was the NewTomDVT9000 (Quantitative Radiology, Verona, Italy). It was solely used for maxillofacial imaging[6].

The images are acquired in one rotation by an image intensifier of the flat panel detector and the resultant image has improved resolution than that of other radiograph techniques. Also, during rotation, multiple sequential planar projection images ranging from 150 to over 600 of the region of interest can be obtained in a complete or partial. Therefore, CBCT is well suited technique for dental and maxillofacial cases and pre implant planning[3]. It is one of the most widely used radiography techniques because of its innumerable benefits.

Like CT, one can obtain voxel values using CBCT. However, it is not possible to obtain accurate Hounsfield units (HU) which makes it unreliable for obtaining bone density as it provided different grey scale values for different areas of scan. It was observed that the HU measured using CT and CBCT did not have identical values. However, after applying a correction has been applied to grey levels with the CBCT, the HU obtained is much similar to that obtained with a medical CT device than the one with original CBCT thus making it reliable for obtaining bone densities and differentiation of various tissues[3].

It is possible to reformat the original image obtained through CBCT like CT. The reformatted CBCT image shows an axial image of the alveolar process along with the cross sectional view of the alveolar and panoramic views. Thus CBCT provides information about the cortical bone plates, the mandible and maxilla along with the detailed proximity of the vital structures with the contour of the soft tissues. It also helps visualize the cancellous bone. The images obtained are much sharp providing precise anatomical location thus making it easier for a dentist to do the pre implant planning since the images almost depict the real view of the mandible and maxilla with great accuracy[3].

Preoperative implant planning is done using the help of imaging stents. By using these stents, precise anatomical location can be assessed. The intended implant sites are identified by a radiopaque marker retained within an acrylic stent which the patient wears during the imaging procedure. Therefore, the image of the stent would be produced in the diagnostic image which would then be useful as a guide for treatment planning[8].

Several diagnostic and planning softwares are made available to assist in treatment planning. When those programs are applied, different diameters and length of implants can be 'tried' before a suitable one is chosen. Apart from that, implant placement can be viewed form different viewpoints and angulation. Once the treatment planning has been decided, it can be saved and applied to surgical sites by means of image-aided navigation[3].

14. The Advantages of CBCT Are[8]

- Real size 3dimensional data
- Potential for generating all 2dimensional images and vertical scanning in a natural seating position
- High resolution
- Low radiation dose
- Less disturbance from metal artifacts
- Reduced cost
- Easy accessibility and handling
- Small footprint

15. The Disadvantages of CBCT Are[8]

- Low contrast range
- Limited detector size which causes limited field of view and limited scanned volume
- Limited inner soft tissue formation
- Movementartefacts affecting the whole database

16. Conclusion

The diagnostic imaging techniques can be used widely for diagnosis, analysis and preoperative planning for surgery and dental implants. We know there are various radiography techniques which provide images of different contrast and clarity ranging from 2 dimensional to complex 3 dimensional images of the region of interest. The two dimensional imaging techniques are economic and has low radiation doses but image does not provide detailed cross sectional view while the 3 dimensional techniques are very effective despite of high radiation doses provides more than enough information regarding the bone, tissues and other vital structures with great accuracy and detail enhancing the success rates of implants. It is good to proceed with panoramic imaging and intra oral radiography to begin with, however, CBCT is the best and a widely used technique because of its various benefits. These computer assisted radiography techniques have helped dentists to restore the teeth and other important diminished structure of partly or completely edentulous patients and making implants lot convenient for dentists as well as the patients.

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